Resources

PART II

Lectures Prepared

by

Dr. Mohammady F. Abu-Elsaud

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Chapter 8
Applied Natural Resource Cases

In this chapter we will examine some specific resource problems. We shall survey some of the most important of these problems, and employ simple tools of economic analysis to clarify them.

1- The Economics of Resource Activities:

In this section we examine a number of issues in the economics of outdoor recreation in its most general sense involves all kinds of activities from setting in the backyard watching birds to using national park outdoor recreation in many developed countries has grown rapidly in the latter part of the twentieth century. Several different perspectives are important in studying the demand for a certain type of outdoor recreation activity among a defined group of people.

Another perspective is what we might call the facilities management view-point. Suppose we are in charge of a particular park, our need would be to develop an understanding of the demand curve facing our single facility, which is affected by population, incomes, transportation

services, and the presence of other competing or complementary areas.

A demand curve of this type is drawn as in the following figure:

Figure (1)

Demand Curves for an Imaginary Public Park

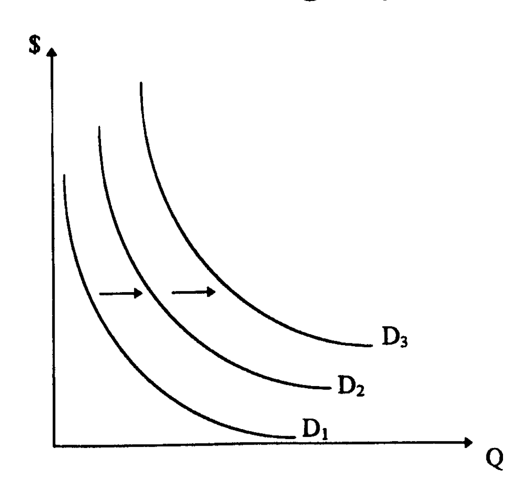


Figure (1) shows a series of demand curves, each is related to a different time period. We can assume that demand curve D_1 is the demand curve for some past years, and that D_2 is the demand curve for the current period. Thus, D_3 is the expected demand curve for a future period. What are the factors behind this shifting demand curve? One of the major ones is the population growth. The others

are: income growth, transportation improvements, and the tastes.

It is easy to hypothesize the existence of demand curves such as the previous, but difficult to estimate them in fact. It is specially difficult to measure how they have shifted over time.

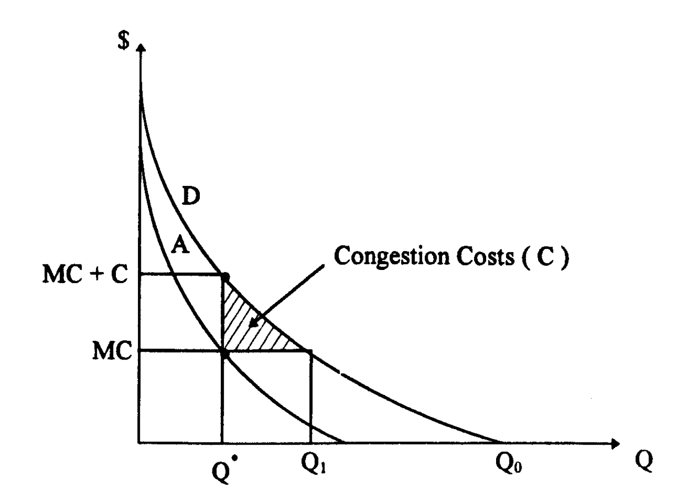
In keeping with the idea of the socially efficient level, the socially efficient visitation rate is the rate that maximizes net benefits to society. If entrance fees are zero, the actual and expected number of visitors will be those shown as the sequence D_1, D_2, D_3 in figure (1). There are two reasons for thinking that these do not represent socially efficient visitations rates. The first, the costs of operating and maintaining the park are not being recovered through admission fees. These costs are covered through some other means, such as taxes. In this case there is a disconnect between the people using the park and the people paying for it.

The second reason for thinking that D_1, D_2, D_3 are not socially efficient is the presence of congestion externalities. If admission fees are zero, we have a situation of open access, open access will normally lead to use rates that exceeds socially efficient levels. Congestion externali-

ties would tend to increase as the demand curve shifts outward, and eventually, once visitation become very high, might choke off any further increases in visitation despite increases in population and other factors.

To examine this idea more closely, consider the following figure:

Figure (2)



The curve labeled (D) is the normal market demand curve for visits to a public park. The point of intersection with horizontal axis (Q_0) gives the open access level of visitation, where there is no entrance fees are charged. Suppose the marginal costs of operating the park are con-

stant at a level of MC. If the price were charged equal to this amount, visitation would go to (Q_1) visitors. This is not necessarily the efficient level of usage, and the reason is that the curve D dose not take congestion affects into account.

When the rate of visitation increases at a public park, the new visitors may cause congestion that lowers the value of the visitation experience, not only for them but also for people who are already there. Ordinary demand curves do not account for these congestion effects because they are based on the willingness to pay of the marginal uses. What we need is a demand curve not of congestion effects, that is, a curve that shows that marginal willingness to pay of the marginal uses minus the congestion costs of existing users. These costs are essentially a reduction in the value of their visits caused by the entry of additional visitors. A demand curve adjusted for the congestion effects is shown as curve A in figure (2). The height of D shows the willingness to pay of the marginal uses, the height of A shows this marginal willingness to pay minus the congestion costs inflicted by the marginal user on existing users. The socially efficient rate is Q^*.

Open access in public parks and recreation areas has led to over use, congestion, and often to the degradation of

natural resources in the areas. In effect, open access leads to use rates like Q_0 in figure (2). This leads naturally to the question of how managers can limit visitation rates to something more consistent with the implications of social efficiency.

Rationing Use: Means finding some way to exclude certain of those who would have visited if open access conditions had continued.

The following list describes various methods available to a managing agency for rationing visitation:

1- Limit entry to those people who meet some pre-specified characteristics.

2- First-come, first-served.

3- Change an entrance fee sufficiently high that visitation is equal to Q^*.

The first two of these are non-price rationing procedures. The last one is called price system procedure. Entry fees to retain use have not been commonly used historically. However, the use of admission fees may be a more appropriate and effective way of raising revenues to support the maintenance of park areas. But since a major rationale for entry fees in practice is to raise revenue, it will be useful to clarify the connection between price changes

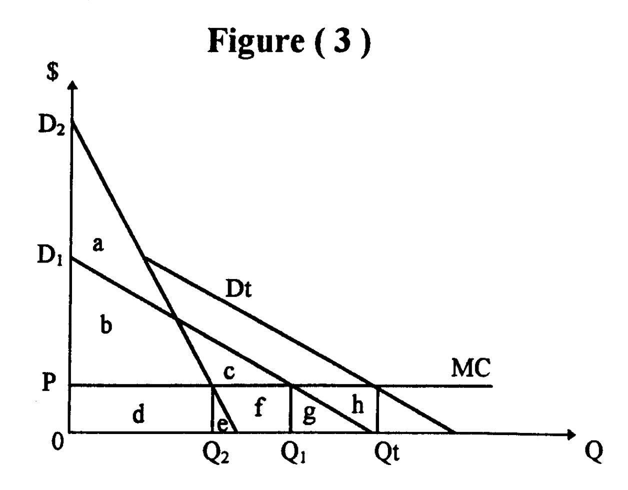
and revenue changes. It depend mainly on the price elasticity of demand, in case of unitary elastic of demand (ε = 1), the total revenue dose not change as the price changes, in case of inelastic demand (ε < -1), the total revenue will increase as price increases, finally when ε > -1, the total revenue decreases as price increases.

The real world, however, is obviously more complicated than the simple model above. The question then is how to establish different prices for different users? Consider the following figure (3) which implies a situation where there are two types of users of a park, one group has a demand curve labeled (D_1), and the other has demand curve (D_2), and the latter (D_2) is steeper than the first (D_1). The aggregate demand curve (D_t) is the horizontal summation of D_1 and D_2.

MC is the marginal cost showing that the marginal cost of servicing all visitors is constant. Let us assume that there are no congestion problem. Overall social efficiency requires that aggregate marginal willingness to pay be equal to marginal cost. The single price that will lead to this is to set price equal to marginal cost (P = MC) for both users. Total visitors will then be Qt and the visitors for both users will be Q_1 and Q_2. Note that total revenue taken in will just equal total costs (the area d + e + f + g + h). Of

this total revenue, d + e + f is paid by group 1 and d is paid by group 2. Net benefits accruing to group 1 are b + c, and for group 2 are equal to a + b. Total net benefits are maximized (social efficiency) when the same price is charged to each type of users.

Figure (3)



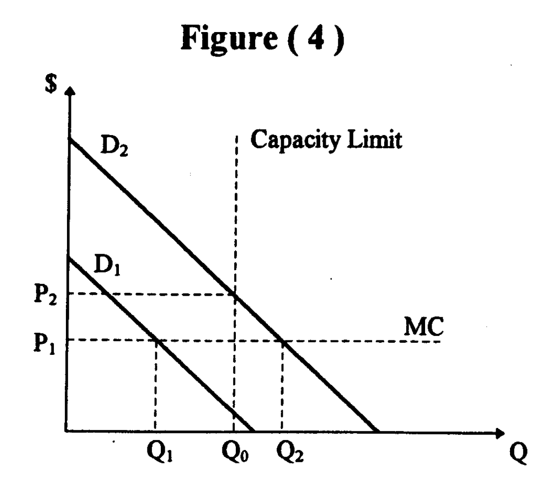
Suppose now we charged $ 10 a day to type one visitors and a $ 5 a day to type 2 visitors, this means that marginal type 1 visitor valued the visit at $ 10, while the marginal type 2 visitor valued it at $ 5. It is not socially efficient to let the former in but keep the latter out. Thus, as long as the marginal costs of servicing individuals in the two groups is the same, there is no efficiency justification for charging different entrance fees. If the marginal costs of servicing people in the two groups are different, efficiency

requires that they be charged different prices. In particular, prices should be higher to the group with the highest marginal cost, and lower to the group with the lower marginal cost.

The rule is: Set P = MC for each subgroup of users will achieve this result.

An example where there is a cost difference is when congestion cost differ from one time period to another. Many parks have capacity limits, consider a very simple case of a park with a certain number of picnic sites, indicated as Q_0 in figure (4).

Figure (4)



Suppose that the marginal costs of servicing the sites is quite low, set at the level MC, there are two demand

curves: D_1 pertains to weekday visitors, and D_2 is for weekend visitors. D_2 is outside D_1 because of the greater time availability that people have on weekends. Efficiency in this case requires two prices. During the week, set P = MC. In this case the average weekday visitation will be Q_1. But this price will not do for weekends, because the quantity demanded at this price on weekends will far exceed the capacity of the park (that is $Q_2 > Q_1$).

Parks might under political pressure to charge the same rates during the weekend that they do on weekdays. In this case some type of non-price rationing would be required to limit the weekend use.

If the price P_1 = MC were set on weekends, we would have no guarantee that people ending up with picnic sites would be those who valued them the most highly. Thus, to ensure a maximum of net benefits, we set P_1 = MC during the weekdays, and P_2 during the weekends. On weekends, total costs are equal to (c + d + e), while total revenue from entrance fees is equal to (a + b + c + d + e); the park is making a profit equal to (a + b). In effect, this is a redistribution of income from the weekend park visitors to who ever ends up with these revenues, perhaps the general taxpayer if they go into a general account of some political entity.

Suppose now that the park agency is under a political directive to operate as a nonprofit, then it would have to restort to some means to avoid making the profit (a + b) There are two possibilities: One is to charge P_1 on the weekends but restort also to non-price rationing as mentioned above. Another is to inflate costs until they match revenues. By "inflate" we mean an undertaking expenses that are not really needed to maintain the park at an acceptable level.

2- Water Resources:

Water resources are critical to human development. Water is a biological necessity for human existence, like air. But the importance of water resources extends to public health, economic development, and the health of ecosystems.

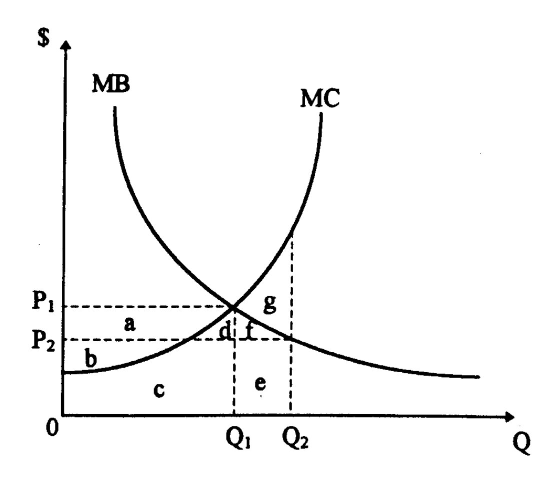
Most of water on earth is salty. Through history this has not been for human consumption, but recent developments in desalination technology and increases in the scarcity of fresh water have turned many communities toward the ocean for fresh water supplies.

Water Pricing:

Politicians and other public authorities have had a lot to say about how water has been priced. This obviously

has had enormous implications for the way water has been used and on the demand for expansion in water supply systems.

Figure (5)



The efficiency implications of average cost pricing are easy to see. Figure (5) shows the supply and demand curve for water for a community water supply system. MB is the marginal benefits function while MC is the long-run marginal cost function based on the costs of delivering water.

Note that the demand curve for water is drawn as downward. Sloping to the right, just like any other good or service. Water is necessary for life, in particular 2 or 3

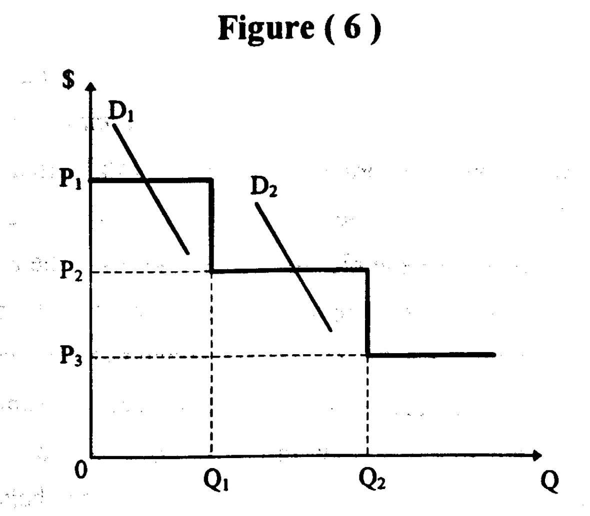
gallons per day that are a biological requirement. The efficient quantity of water is Q_1 gallon per year, and the market clearing price for this is P_1 per gallon. Suppose the water company changes this price. Total costs of water supply is an amount equal to the area (c +d). But total revenue is equal to price times quantity, or the rectangle (a + b + c + d) which clearly exceeds the amount (c + d). So if the utility sets its price this way, it will be running a profit. To avoid profit, therefore utility usually price below marginal cost, for example, something like P_2 in the Figure (5). By setting the price in this way, it can find the point where total cost (c + d + e + f + g) is equal to total revenue (b + c + e). But a price like P_2 is not efficient. The amount of water demanded at that price is Q_2, and if the utility produces at this level, there will be a discrepancy between marginal cost and marginal benefits, the later will be below the former. The utility will be producing some water for which the marginal valuation of consumers is lower than the marginal costs of production.

Declining Block Pricing:

A practice in which many water companies have historically engaged is declining block pricing. Under this pricing scheme, consumers pay a relatively high price for some initial quantity of water up to some maximum and

then pay lower prices for quantities in excess of this level. There may be several declining blocks, as pictured in Figure (6).

Figure (6)



For any quantity at or below Q_1 gallons per month, the consumer pays a price of P_1. For a quantity of Q_1 or more but less than Q_2, the price drops to P_2 and for quantities of Q_2 or greater, the price drops to P_3.

The justification normally given for declining block pricing is that the cost per gallon of water delivered to large consumers is lower than the costs per gallon of getting water to smaller consumers. An even stronger element of justification for declining block pricing historically has

been that it offers an economic advantage to commercial and industrial water users.

From an economic standpoint, declining block pricing has two major limitations. First, it tends to encourage water use. If the price of something gets lower the more of that something, incentives to converse are weakened. In fact, it produces incentives to expand water consumption to take advantage of lower prices. Second, or from a slightly more technical standpoint, declining block pricing is also likely to upset the conditions for economic efficiency. In Figure (6), suppose that there are two water users, one with the demand curve labeled D_1 and the other with D_2. The D_2 consumer will end up consuming more water than the D_1 consumer and will be on the second block price for water. This means that the price paid for one more gallon of water will be higher for D_1 consumer (it will be P_1) than the marginal price paid for the D_2 consumer (which will be P_2). But to have two consumers paying different prices for the same commodity is a violation of standard efficiency conditions, unless of course the two consumers differ in terms of the costs of delivering water to them. To see this, note that what would happen if a gallon of water was reallocated from D_2 consumer to the D_1 consumer. The former would lose something that has a

marginal valuation of P_1. Since $P_1 > P_2$, the total value of the water has been increased simply by reallocating a small quantity from one user to another.

Declining block pricing is likely to violate one of the principles of economic efficiency, which is that all users should pay the same price for the item.

Investing In Water Supply Systems:

The discussion of how existing water supplies are located - especially how water is priced - can give us some very interesting insights into the ways water is used and misused and into the efficiency and equity implications of changing water utilization practices. Throughout the country, however, communities and water supply companies are faced with a whole range of investment decisions related to the overall size or capacities of their systems. These situations might include, for example:

1- Investments to protect existing water supplies (e.g., a community has to decide whether to buy land in the watershed area around its reservoirs so that development on these lands will not threaten water qualities and quantities in the reservoir).

2- Shifts from one type of water supply source to another (e.g., a coastal community faced with saltwater intru-

sion into groundwater supply considers whether to switch to a desalination plan).

3- Investments in the existing system that have the effect of increasing system capacity (e.g., a community may decide to replace some of the existing water mains to reduce leakage).

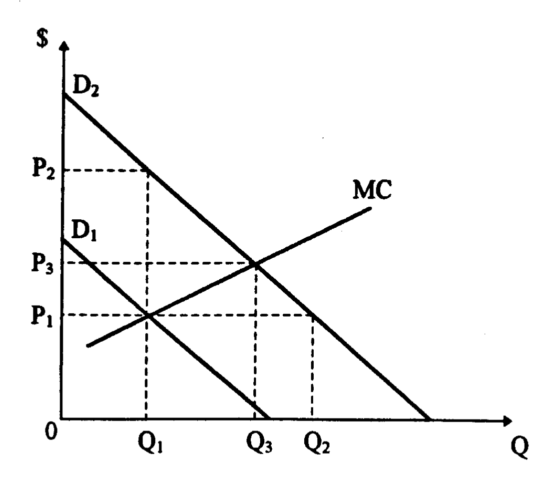
4- Expansions of the existing system (e.g., a community has to decide whether to build an additional reservoir or new water canals to another surface water source in order to increase the capacity of its total water supply system).

All these situations call for investment0type decisions, that is, decisions in which most of the costs occur today or in the near future whereas most of the benefits are in terms of future consumption values -often very distant ones. Cases like this require techniques that we have discussed earlier for making decisions that have future consequences: some way of predicting accurately what future costs and benefits will be, and the discounting of future values so that all investment costs and benefits are in terms of present values.

But in reality it is not really possible to separate the water pricing problem from the water system investment

problem. Investments affect future supplies, and prices will affect future demands and thus the balance between demand and supply. Consider Figure (7). Suppose that at the present time the water demand curve for the community in question is D_1 and the price of water is currently P_1. This means that the quantity of water demanded is Q_1. Suppose that this quantity Q_1 is also equal to the present capacity of the water system, Thus there is a balanced situation, with neither excess demand nor excess supply in the system.

Figure (7)



Suppose also the community believes that because of anticipated economic and demographic growth, future water demand will also grow. For purposes of illustration,

suppose that in 10 years the water demand curve is expected to be D_2. The community must now give thought to its water supply system. If it does nothing, and the new population materializes anyway, there will be excess demand at the old water price of P_1. At that price, with demand curve D_2, the quantity demanded of water is Q_2, which is substantially in excess of the capacity of the current system at Q_1. The excess demand could be wiped out if the price were raised to P_2, because even with the expanded demand, the quantity demanded at this higher price would not exceed the capacity of the current system.

It's unlikely that water planners would countenance such an increase in water price, however. Not only would consumers have to pay much higher prices, but the water utility or company would probably be making sizable profits in that situation. More than likely, the planners would think in terms of adding capacity to the system by investing in additional water supplies (enlarging a reservoir, adding a new reservoir, or perhaps drilling additional wells). There is where price comes in. If the planners seek to maintain the current price of water, they will need an increment to capacity of Q_2 - Q_1 million gallons per day, because at a price of P_1, quantity demanded with the higher demand curve is Q_2 million gallons per day. If future prices are

somewhere above P_1 but below P_2, then the increment in capacity could be somewhere greater than zero but less than $Q_2 - Q_1$. What's the right course of action?

There are several ways of answering this question. From the standpoint of economic efficiency, however, the answer depends on how much it will cost to increase the capacity of the system. In technical terms, it depends on the shape of the long-run marginal cost curve (i.e., the supply curve) for water. Suppose this is horizontal, in other words the system can be expanded in such a way that the costs (capital costs plus operating costs) of delivering the water are constant. Then, indeed, the efficient system increment is equal to $Q_2 - Q_1$, and the efficient price of water would remain at P_1.

But suppose the long-run marginal costs of added capacity are upward-sloping, such as is depicted in the curve labeled MC that goes through the original price-quantity combination P_1, Q_1. This would be the case, for example, if it becomes increasingly costly to add capacity. We would probably expect this to be the case, especially in arid or semiarid conditions. Cities may find that they have to reach out farther to get additional water supplies, or they may have to bid additional water supplies away from other users at higher prices than they are currently paying. Even

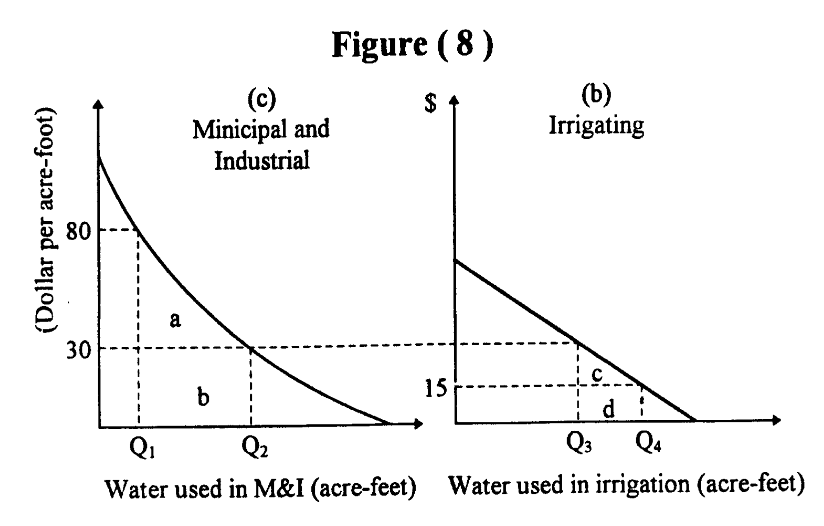
in relatively humid areas, marginal costs may increase if people have to turn to increasingly costly sources of water. With rising marginal costs, the efficient course of action is some combination of higher price and added quantity. With the MC curve as depicted in Figure (7), the efficient course of action would be to increase system capacity to Q_3 and raise the price of water to users to P_3.

Water Transfers:

In the world of water resources, large differences in water prices among users is fairly strong evidence that this normal adjustment process has not worked. Figure (8) shows two water demand functions. The one on the left is that for municipal and industrial (M&I) water used in an urban area. The one on the right is that for water used in irrigation in the nearby farming area. Let us suppose that the cost per acre-foot of delivering water to the two uses is exactly the same. Because of the way water rights have been allocated in the past, the city is currently consuming Q_1 acre-feet of water while irrigation are applying Q_4 acre-feet of water to farms. The marginal value for M&I purposes is P_1, whereas that for irrigation water is P_3. These are clearly very different. If we reallocated just 1 acre-foot of water from agriculture to M&I, we would have a gain of P_1 in the latter and a loss of P_3 in the former, hence an

overall net gain of $P_1 - P_3$. In this figure some illustrative dollar numbers have been put on the vertical axis to help in understanding the problem. The marginal value of water for M&I is currently $80 per acre-foot. That for agriculture is $15. Gains from trade clearly exist. If an acre-foot of water is reallocated from agriculture to M&I. the net gain is $65 (the $80 gain in M&I minus the $15 loss in agriculture). As long as these marginal valuations differ, reallocations will continue to have positive net benefits. Thus, the total gain would be maximized by reallocating to the point where the marginal valuations are equal, which is at a price of $30 in the figure. At that point, Q_2 acre-feet would be going to M&I and Q_3 irrigation. The total net gain from the reallocation would be (a+b)-(c+d).

Figure (8)



Suppose we have a situation like this in the real world. Should the water transfer be allowed, in whole or in part? Should it be facilitated somehow through public action? If so, how? If the commodity we were talking about were potatoes, we probably wouldn't spend much time worrying about it, because we would expect the flow of potatoes around the market to adjust to price discrepancies like this. But water mat be different. Or is it? Historically, nobody has worried about potato rights, but water rights have long been something to fight over. If water is reallocated among users, and perhaps shipped from one location to another, the potential economic impacts could be far reaching. Consider the question of how the transfer is to be made. In keeping with earlier distinctions we made between different types of policy approaches, there are two basic ways of doing this: an administrative action by a public regulatory agency or transactions on a market for water rights.

An administered shift in water rights would be carried out by having a public agency, such as a state department of water resources, reduce one party's water rights and confer these rights on another party. This would be done by fiat, after ascertaining that the shift is in the public interest and using standard regulatory enforcement proce-

dures to make sure that the change goes through. Changes of this type, especially large-scale shifts among different types of users (e.g., farmers vs. urban dwellers), usually spark energetic legal and political struggles that pit one side and its allies against the other side and its allies. The outcome would probably depend as much or more on the political strengths and abilities of the participants as on the economic values (benefits and costs) of the proposed transfer.

The other way to effect the transfer is through transaction on a market for water rights. Market transactions occur because willing sellers meet willing buyers and trade something of value at a price agreed to by both participants. The buyers gain an amount (a+b) from purchasing Q_2 - Q_1 of additional water in Figure (8). The sellers lose an amount equal to (c+d). It's possible to find a price per acre-foot that, when multiplied by (Q_2 - Q_1), the quantity traded, will allow both participants to gain from the trade. It will be lower than the gain experienced by the buyer, and higher than the loss of the seller.

Instream Flow Protection:

Historically most conflicts about water rights and utilization centered on water withdrawals, where water

was physically removed from stream or lake for irrigation, mining operations, manufacturing needs, and so on. Many rivers, especially in the West but even in the East as well have reached points where most of the water is fully used or appropriated, leaving very low instream flows, especially in the drier seasons of the year. In recent decades, however, the values produced by water that is left in its natural location have become much more obvious and important. Thus there has been a growing demand for the protection of instream flows. Instream flows protect the estuarine environment and its ecological and aesthetic values. They are also the basis for a large and growing segment of the outdoor recreation market: fishing, white-water and flat-water sports, hiking and camping, bird watching, and so on.

The legal status of instream flow water rights varies from state to state. In most cases the major players in protecting instream flows are public water management agencies, and so groups and individuals who seek to increase instream flow have to work within the political process in which these agencies are embedded. A natural extension of the water rights marketing concept would be to allow individuals or groups to buy instream water rights. Naturally, traditional water withdrawers are quite reluctant to move in

this direction, as it could lead to major shifts in the way water is managed.

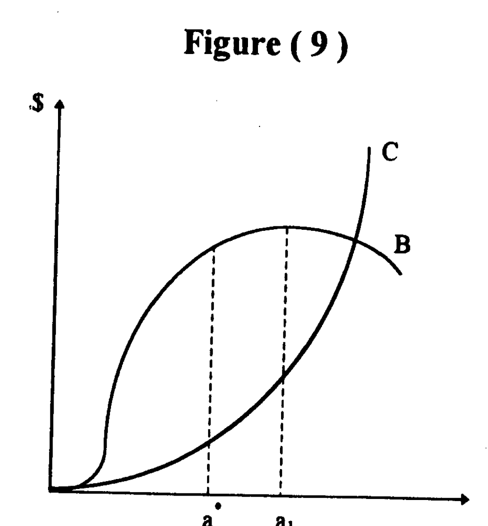
Optimal Instream Flows:

How much water should be left in a stream? It is easy to think about this conceptually, through difficult to determine very precisely in practice. Figure (9) shows the benefits and costs of instream water flows, and how these benefits and costs change as flows change. The curve labeled B shows benefits, starting to the right of the origin. Some minimal amount of water is necessary before any benefits appear at all. The function increases, reaches a maximum at a_1, and then begins to decline, because still larger flows actually reduce most instream values. This is an illustrative benefits function shape; the actual shape would of course vary from one real-world situation to another.

The cost relationship is labeled C; it rises to the right and becomes increasingly steep. The primary costs of instream flows are the value of forgone water withdrawals. Since the values of different types of withdrawals (e.g., agricultural vs. urban) differ, the cost curve is drawn under the assumption that it captures the most valuable forgone alternative use. The instream flow that maximizes total

benefits is not one that maximizes net benefits; the former is a_1 and the latter is a^*. The reason for the discrepancy is that costs are taken into account in one case but not in the other. Note that at a^*, marginal benefits (the slope of the B curve) are equal to marginal costs (the slope of the C curve).

Figure (9)



There is a certain amount of ambiguity in this model, since it is so simple. The horizontal axis indexes quantity of water per day. But most rivers and streams; unless they can be completely controlled through upstream impoundment, have flows that fluctuate from day to day and season to season. So we might think of the horizontal axis as

measuring the mean value of instream flow over a year's time. On any single day the flow might be somewhat, or perhaps substantially, below the average. And this would affect the benefits and costs produced by the river over the course of the year. In other words, you could have two rivers, each with the same average instream flow but with very different variation about the mean. In this case benefits and costs would likely be different between the two.

An interesting question is, how sensitive are net benefits to changes in stream flow? If flow is not at a^* but above or below it a certain amount, will this substantially affect net benefits? The answer to this is reflected in the shapes, especially the curvature, of the benefit and cost curves. If the curvature is low in both cases, then any flow rate around a^* will be almost as good as any other. If the relationships are very curved, then the opposite is true, and a flow of exactly a^* is required to ensure maximum net benefits.

While the logic Figure (9) is straightforward and clear, its application in any particular real-word case is going to be difficult. One problem is just getting the necessary data to determine the relationships; data are required on both benefits and costs. Another major problem is that very often there is more than just one type of instream

benefit, and the best flow rates may very well differ among the benefit types. The flow rate that is best for maintaining a trout fishery, for example, may be very different from the best flow rate for maintaining white-water rafting activity.

3- Mineral Resources:

"Mineral" refers to the wide range of inorganic solid substances, which are normally found in or on the ground and which are used by humans for a great variety of purposes. We can distinguish between **fuel** and **nonfuel minerals**; the former will be covered in the chapter on energy. Nonfuel minerals can be further subdivided into **metals** and **industrial minerals**. The major classes of metals are the **ores**, such as iron, nickel, and bauxite, and the **precious metals**. Important classes of industrial minerals are the **natural aggregates** (crushed rock, sand, gravel), **cement, fertilizer minerals** (phosphate rock, potash), abrasives, and gem stones.

A mineral appears to fit the classic definition of the **nonrenewable** resource, one for which $\Delta S = 0$. For a given deposit, the quantity of material would appear to be strictly nonreplenishable, hence one that can only be drawn down over time. In the next section we see that this state of affairs is somewhat ambiguous, because minerals normally

exist in different **grades**. The notion of nonrenewability is sufficiently compelling in the case of minerals, however, that our first analytical job will be to explore conceptually the simple but classic question: Given that there is a certain quantity of a nonrenewable resource available in a deposit, how fast should it be extracted and used? We then take up the broader question of **exploration, discovery, and development** of mineral deposits, where the question is no longer only how fast to run down known stocks but also how much to spend on finding new stocks. Finally, since minerals are the major component of materials, we focus on the economics of recycling.

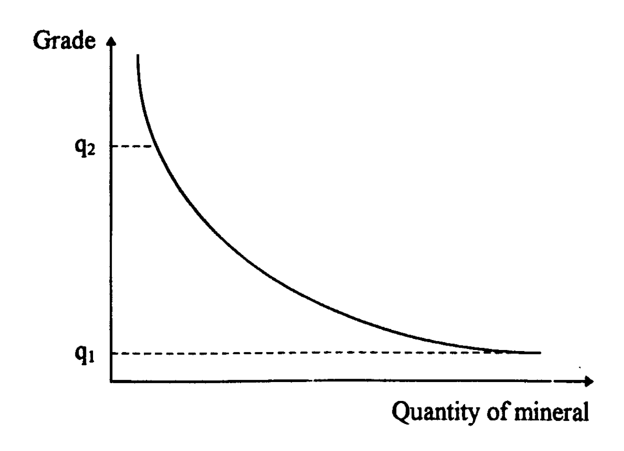
Geological Factors and Costs of Extraction:

Copper is widely distributed throughout the world In fact the copper content of a randomly chosen bucket of the earth's crust contains 63 parts per million (ppm) of copper. But copper is actually mined in a selected number of spots, where the concentration of copper in the ore is substantially higher than this. It is high enough, in other words, that it can be extracted and refined at reasonable cost, with current extraction technologies, Thus, although copper (and most other minerals) is a nonrenewable resource in some ultimate physical sense, there is actually a long grade-quantity continuum like that pictured in Figure

(10). Relatively few very high-grade deposits exist, but at progressively lower grades, the potential supply increases Some very low-grade deposits, indicated by g_1 in the figure, correspond to average crustal abundance of the mineral, at which the potential supply is extremely large. The profile appears to be very definite, but it is actually quite speculative. Under technology available at present, there is some **cutoff grade**, such as the one indicated by Q_1 in Figure (10), representing the minimum grade that can be economically extracted and refined. Geological exploration and conjecture may give us a reasonably good idea about how much is currently available at or above this cutoff grade, but how the relationship looks between g_1 and g_2 is much more uncertain. It may rise smoothly and steeply, or it may have bumps at various points. The actual relationship will be revealed only in the fullness of time, as geological theory and exploration progress.

Figure (10)

Relationship between Grade (Mineral Content per Quantity of material) and Total Quantity



Thus, as the mineral grade decreases, known and expected quantities increase. Also, as grade decreases, the costs of extraction and refining increase. So when it comes to the economics of extraction and supply for "nonrenewables" like minerals, there are essentially two questions to address: (1) Given a deposit of known quantity and grade, what is the socially efficient rate at which that deposit should be used up: (2) What is the economically efficient rate at which geological exploration should be pursued in order to expand our knowledge of known deposits? How much should be devoted, in other words, to

geological exploration and discovery? We focus on these two questions in turn.

Extraction Economics For A Known Stock:

In this section we look at the simple economics of a nonrenewable resource in which the basic question is: Given that there is known quantity of a nonrenweable resource, how fast should it be extracted and used? To address this in a simple but revealing way, we limit the analysis to just two time periods, this year and next year. A two-period analysis is clearly unrealistic, but the essence of efficiency in this case is the balance that is achieved between "today" and the "future", and the logic of this trade-off can be explored quite well with simple model.

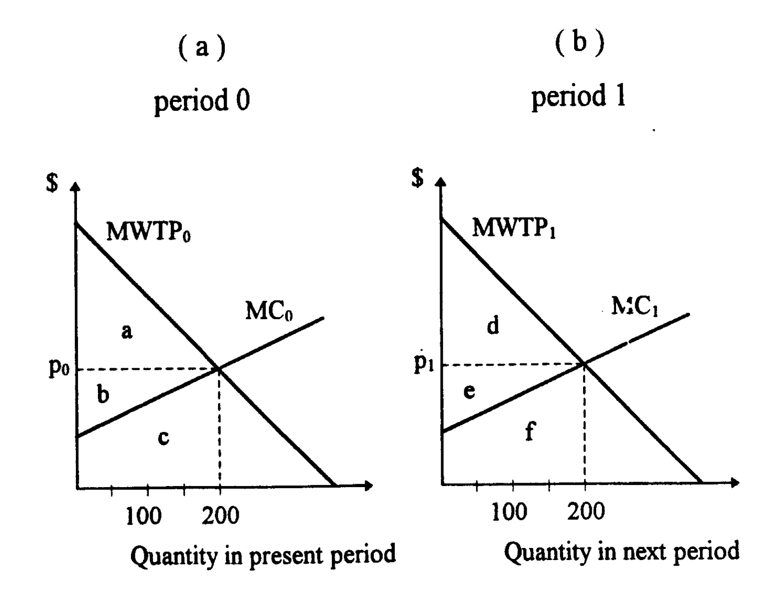
Suppose there exists demand or marginal willingness-to-pay curves for this resource in each of the two years, as shown by the MWTP curves of Figure (11) (a) and (b). They are the same. Today, the MWTP curve is known because it is happening now, and the assumption is that the MWTP curve of the next period is going to be like that of today's [1]. The marginal extraction cost curves, la-

[1] Of course if the next period's MWTP curve is highly uncertain, this may add some complexity to the problem that we might want to explore, but for now we overlook this issue.

beled MC_0 and MC_1 are also expected to be the same; they are, in fact, linear and sloped upward to the right, as depicted in the figure. These are assumed to be the aggregate marginal cost curves for a competitive extraction industry, that is, one composed of a substantial number of individual firms.

Figure (11)

Extraction of a Nonrenewable Resource



According to the situation depicted in Figure (11) (a) and (b), statically efficient extraction levels of this re-

source (identified by the condition MWTP = MC) are the same in each period : 200 units[1] . If the total quantity of resource available were greater than 400 units, there would essentially be no problem; the resource could be extracted at its static efficiency level in each period. The efficient multiple-period production plan in this simple case would be to produce the same output each year. But suppose the total amount of this resource were less than 400 units, for example 300 units. An extraction rate of 200 units each year for 2 years now would exceed the total availability of the resources; thus **extracting more today means having to extract less next year, and vice versa**. In order to determine our efficient intertemporal production plan, this overall limit on the amount of the natural resource must be taken into account.

It is easiest to work this problem out with a little algebra. Static efficiency required the choice of a single output rate, but it is now necessary to identify, simultaneously, two rates of output, one for the first year and one for the second. As mentioned above, the maximand in the multi-

[1] Remember again the convention we are using. The present period is indexed with 0, and the next period with 1. Thus, q_0 and q_1 refer, respectively, to current (this year's) output and next year's output.

ple-year case is the present value of net benefits, which in the case of the two-period model is given as :

$$\text{Present value of net benefits (PVNB)} = \left(\text{Net benefits in year 0}\right) + \frac{1}{1+r}\left(\text{Net benefits in year 1}\right)$$

Remember that r is the discount rate.

The **trade-off** inherent in the intertemporal problem is depicted in the two terms to the right of the equals sign Starting from some initial output levels q_0 and q_1, if q_0 is changed, it will change the first of the right- side terms in one direction, but also, through its impacts on q_1, will change the second of the terms in the **opposite direction**. If output increases in period 1, it must decrease in period 2. The two output rates that give a maximum of PVNB are the rates where the change in this year's net benefits and the change in next year's net benefits (discounted) are exactly offsetting. This condition can be written as :

$$\text{change in net benefits in year 0} = \frac{1}{1+r}\left(\text{change in net benefits in year 1}\right)$$

If the output in either of the years is changed a small amount, the change in bet benefits is equal to MWTP - MC for that year. Thus, the last expression can be rewritten as :

$$MWTP_0 - MC_0 = \frac{1}{1+r}\left(MWTP_1 - MC_1\right)$$

The intertemporally efficient time profile of extraction is the two extraction rates q_0 and q_1 that satisfy this equality.

Let us now shift from MWTP to price. Any quantity corresponds to distinct level of MWTP. Any quantity also is associated with a distinct **market clearing price**, that price for which the quantity demanded exactly equals the quantity in question. In competitive situations, prices will adjust to their market clearing levels. In fact, the market clearing price for any quantity is the MWTP for that quantity, and so we can replace the last expression with :

$$p_0 - MC_0 = \frac{1}{1+r} (p_1 - MC_1)$$

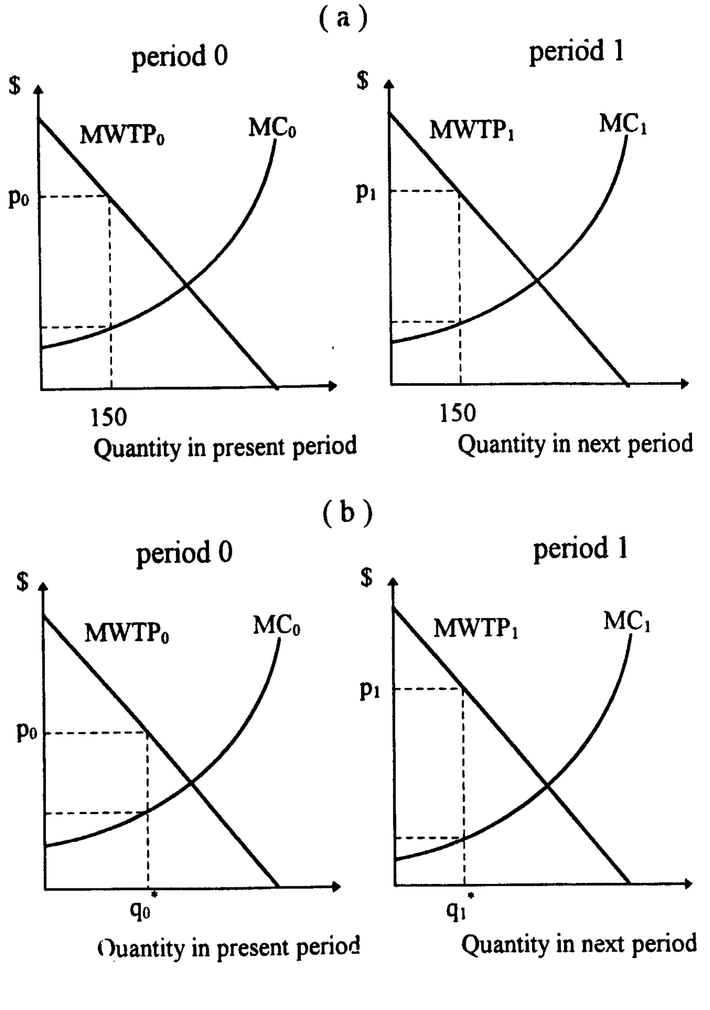
To draw out the implications of this last expression, consider an initial production profile in which $q_0 = q_1$, as depicted in panel (a) of Figure (12). Since both marginal willingness-to-pay curves and marginal cost curves are the same in the two periods, this production profile would imply that $p_0 - MC_0 = p_1 - MC_1$. But if this were true, it would also be true that

$$p_0 - MC_0 \neq \frac{1}{1+r} (p_1 - MC_1)$$

as long as $r > 0$. This means that the equal production profile ($q_0 = q_1$) does not satisfy the condition for in

Figure (12)

Panel (a): A Flat Productive Profile. Panel (b): An Intertemporally Efficient Production profile



tertemporal efficiency. To satisfy that condition, the term on the left of the last expression must be reduced and that on the right must be increased.

The way to accomplish this is to increase q_0 and decrease p_1, because increasing q_0 will decrease p_0 - MC_0 as we move down the $MWTP_1$ curve, and therefore increase p_1 - MC_1. So this leads to the following conclusion: The dynamically efficient production profile involves a "tilt" toward the present, in the sense that extraction in the first year q_0 exceeds that of the second year q_1. This situation is depicted in panel (b) of Figure (12), with the efficient values of q_0 and q_1 labeled q_0^* and q_1^*.

Having found that intertemporal efficiency implies $q_0 > q_1$, we now see (on the assumption that the demand and supply curves are the same in each period that it also implies $p_0 < p_1$. In other words, the efficient production profile also implies a rising price profile. In an intertemporally efficient situation, the **extraction profile is tilted toward the present** and the **price profile is tilted toward the future**.

User Costs:

One of the ways to analyze the above situation is with user cost. In this two-period example, an increase of

one unit of extraction today means a decrease of one unit in period 1; the value of the latter would be a sum equal to the future marginal willingness to pay p_1 minus future extraction cost MC_1. The user cost, in other words, is p_1 - MC_1, and its present value is :

$$\frac{1}{1+r}\left(p_1 - MC_1\right)$$

Figure (13) shows a new version of the efficiency aspects of choosing a present period extraction rate, one that incorporates the user costs of first-period extraction decisions. The marginal willingness-to-pay curve is the same as before, as the MC_0 curve, showing marginal costs of first-period extraction. The dotted curve that starts at $q_0 = q_0^0$ and goes up to the right is the user cost. At rates below q_0^0, user cost is zero, because at this rate or anything below, this first-period use is so low that it would not detract from availabilities in the next period [1]. The solid line labeled MC_0 + UC shows the sum of marginal extraction

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[1] For example, suppose the total availability is 300 units. We know that extraction in the next period would never exceed 200 units (refers back to Figure 10) because MC > p beyond 200 units. Thus, if the use rate in year 0 is less than 100 units, there will be no economically relevant restriction on availability in year 1; that is, user cost below 100 units will be zero. Above 100 units, of course, user costs are positive and increasing, as pictured in Figure (13).

cost and user cost. This curve intersects the $MWTP_0$ curve at an output level of q_0^*, which is the efficient rate of output in the first period. Compare this to the static efficiency level q_0^1.

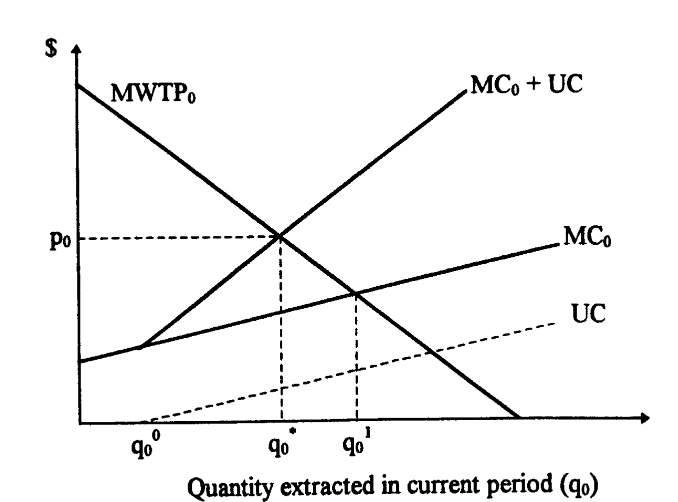
As we discussed earlier, the concept of user cost provides a useful way of thinking about how efficient current and future extraction rates would be affected by changes in some of the factors in the model. Suppose, for example, that we expect the marginal extraction costs in period 1 to be higher than those of period 0, because smaller resource stocks make extraction more costly [1]. There is now another consequence of increasing first-period extraction rates, and this will have the effect of increasing the user cost. Current extraction, in other words, not only reduces future availabilities but also makes future extraction more costly. The increased user cost in period 0 implies that the first-period efficient extraction rate is decreased. So the expectation of future extraction cost increases results in a smaller degree of tilt in the time profile of extraction rates, as compared to the case of no increase in extracting costs.

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[1] In fact, for many resources, extraction costs have been decreasing for a long time technological change has been the dominant factor in this long-run trend.

Figure (13)

Efficient Extraction Rate in Current Period



Another future change that might be expected is population growth. This would have the effect, in our simple model, of pushing out the MWTP curve for the second period. And this would have the effect of increasing the user cost of extraction today. The implication is that the intertemporally efficient rate of extraction in period 0 would decrease. This is true of other factors, such as income growth, that have the effect of shifting out the future demand curve.

This abstract modeling exercise tells us something about a time profile of resource extraction that would be intertemporally efficient. We know that competitive markets with profit maximizing firms having good foresight will produce efficient use rates; this is true in both static and dynamic situations. So if we have a nonrenewable resource with a reasonably competitive extraction sector, we might expect to see the results we got above: diminishing extraction rates and increasing market prices over time.

In fact, for very few, if any, nonrenewable resources do we see this pattern in the historical record. Instead, we see, almost everywhere, **increasing extraction rates** and **declining prices**. How do we explain this? One immediately obvious factor could be increases in populations and in real incomes. By shifting out future demand functions relative to today's, this would lower current user costs and shift extraction profiles more toward the future. We might still expect prices to go up, however, as resource scarcities become more pronounced. Yet we do not observe them going up. Why ?

Resource Exploration and Development:

A major factor that we have to bring in at this point is the cost of natural resource **exploration, discovery, and**

development, that is, the costs of adding to reserves. Individual deposits usually contain fixed quantities of a resource, but it is unlikely to be true that all deposits are currently known. In most cases, exploration and development can increase the inventory of known deposits. With continuous exploration effort, the stock of new deposits, or new reserves, may be pushed out more or less continuously. Of course the effectiveness of exploration and development will vary from mineral to mineral. We will see, for example, that some capable people are predicting a substantial falloff in the rate of discovery of new petroleum deposits in the world. But for many minerals we may expect new deposits to be found and developed with some regularity.

Another important phenomenon is developments in extraction technology. Better extraction methods can make it possible to extract resources of lower grades. These new methods will expand the available inventory of extractable deposits, similar to the exploration process discussed above, Let us suppose that we can summarize these factors with what we will call a **resource discovery function**. As pictured in panel (a) of Figure (14), this shows the **marginal cost of expanding reserves**. It is drawn with a positive and increasing slope, At a reserve level of r_1 the mar-

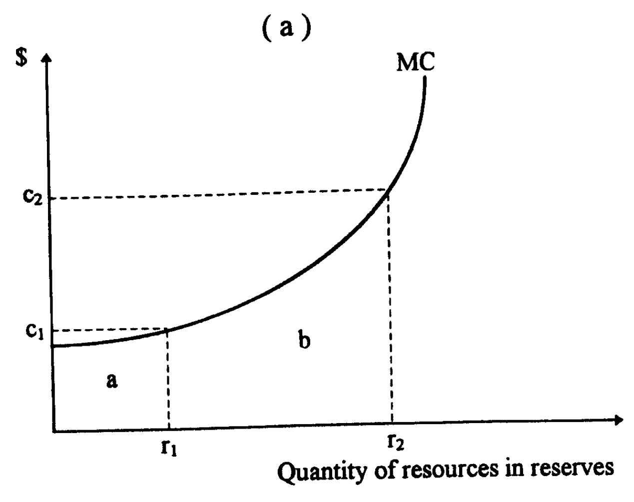
ginal cost of an additional unit of reserves is c_1. Expanding reserves from r_1 to r_2 units would take a total of b dollars, and at r_2, marginal discovery costs would be c_2. Remember that we are talking here about the quantity of reserves, not the quantity of material extracted.

Panel (b) of Figure (14) depicts the supply and demand circumstances for reserves. The supply functions is simply the marginal cost function depicted in the top panel. The demand function represents the willingness to pay a firm or firms for additional quantities of reserve. The intersection of these curve shows the market price that will tend to be established for quantities of materials held in reserve. Furthermore, this price is sensitive to technological changes that take place in the reserve discovery function. These technological changes are represented by a downward shift in the resource discovery function. In the figure the marginal costs of discovery function shifts from MC_1 to MC_2 . As it shifts downward because of these technical improvements, the price of reserve quantities goes down, and the quantity of reserves increases.

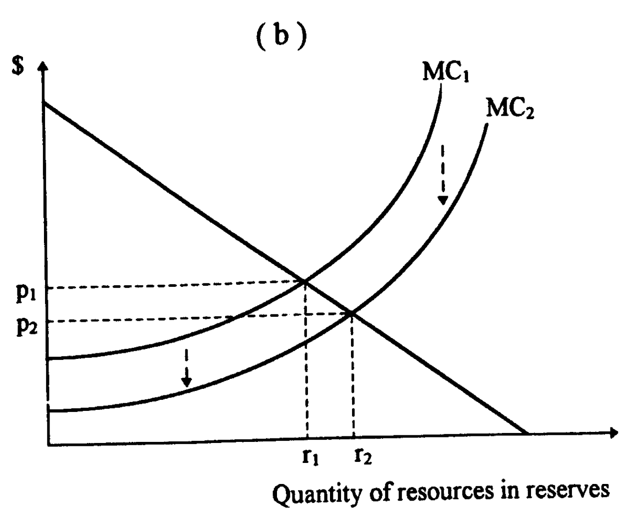
Figure (14)

Resource Discovery Function

(a)



(b)



Consider now a firm that engages in resource extraction and exploration. It has essentially two big decisions to make: (1) how much to extract this year and (2) how much effort to devote to expanding reserves. These two decisions are closely related. A way of understanding this is to see that a firm (or group of firms) in this position has essentially two ways of adding to future stocks: (1) by reducing today's extraction rate and (2) by finding new stocks. If the firm is making efficient decisions, it will adjust so that the marginal costs of these two activities are the same. But the cost of adding to reserves by cutting back today's extraction is simply the rental rate, or in situ price of the resource, while the cost of adding to resource stocks is the marginal cost of discovery. What this chain of reasoning allows us to conclude is that there is another important factor behind the perceived historical drops in mineral prices : the historical reductions in exploration and development costs.

The Economics of Recycling:

Recycling of nonrenewable resources serves both to reduce the draft on virgin supplies and to reduce the discharge of associated residuals back into the natural environment. Many resources change their chemical and physical nature so much during utilization that they cannot

be recovered in useful form. This includes, for example, fossil energy resources, fertilizer minerals, and food resources such as fish and game. Other resources, however, finish their useful lives in forms that can be recycled as raw materials back into the production process. This includes many metals. wood and paper, and chemicals derived from petroleum.

The sequence of steps linking the initial removal of the material from the waste stream and its final reincorporation back into a final product can be complex both physically and economically. It starts with the end users of the material in material in question; either they or some other entity must extract from the waste stream those materials destined for recycling. These materials then will often move through a sequence consisting of various combinations of steps: transporting, sorting, reconcentrating, reprocessing, and finally reuse. Sometimes these functions are accomplished by a single firm, but in most cases the activities of many different firms are coordinated by markets and by the forces of supply and demand that affect them.

There are several important questions when it comes to recycling. Suppose we target a particular material, say, aluminum cans. These can be manufactured from virgin

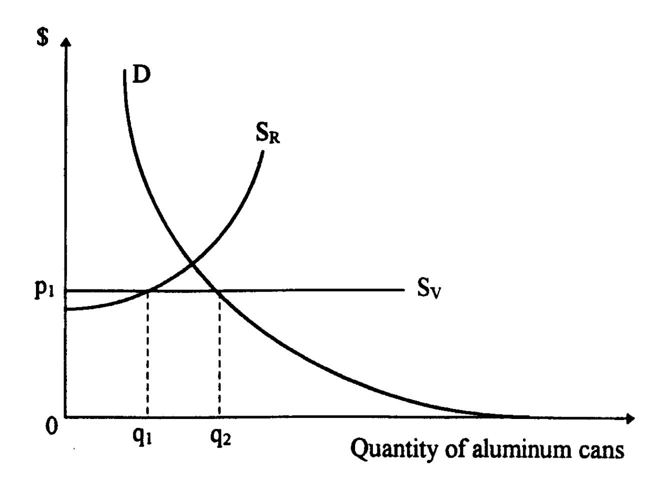
raw material, the cost of which covers mining the bauxite, refining this into alumina and aluminum, and finally manufacturing the cans. The cans can also be produced, in whole or in part, from used cans. The cost of the recycling covers retrieving them from the waste stream, reprocessing the aluminum, and then manufacturing the cans. There are several questions to ask here. First : What is the economically efficient level of recycling in this case? Next : Will current markets tend to produce this level of recycling, or is there a role for public oversight and perhaps intervention? If the answer to the latter is yes, what kind of policy is appropriate?

Figure (15) shows a very simple analysis of the recycling question; we can use it to look at how markets normally will function and the conditions under which they will be efficient. The demand curve, labeled D. shows the market demand for aluminum cans. It's drawn with the standard downward-sloping shape; the higher the price, the fewer the cans demanded, and vice versa. S_V is the supply curve of aluminum cans using virgin raw materials. It's drawn quite flat, based on the assumption that additional quantities of cans can be produced from this source at roughly constant marginal cost. S_R is the supply curve of cans made from recycled aluminum cans; it is sloped up-

ward rather steeply, based on the assumption that recycling is subject to increasing marginal costs.

Figure (15)

The Efficient Amount of Recycling



This is an extremely simple model, but it can be used to reveal some interesting conclusions. According to this analysis, the total quantity of cans sold will tend toward q_1, given by the intersection of S_V and D. The price of cans will be p_1, which is the price established by the level of virgin production costs. This bears repeating : The factor governing the market price of cans is the **cost of production from virgin sources**. The quantity of recycled cans will be q_2; if recycled output were pushed beyond

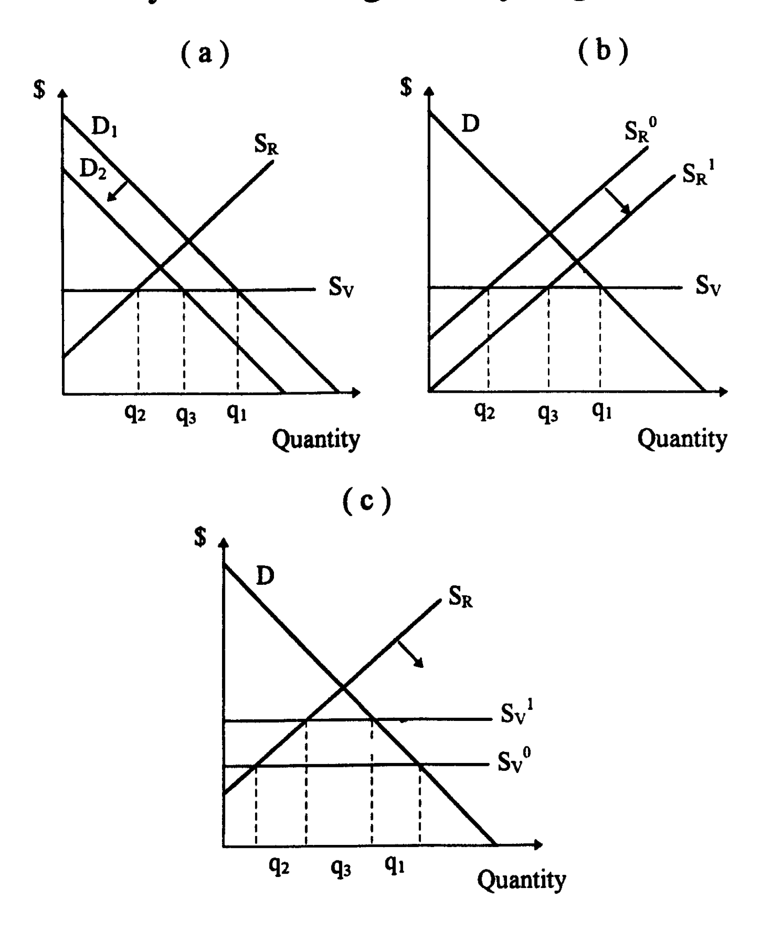
this, costs would rise above p_1, which would not be feasible in a competitive world. The quantity of cans produced from virgin material is $q_1 - q_2$, and the recycling ratio, the proportion of total cans that stem from recycled sources, is q_2/q_1.

Figure (16) looks at the different ways that are possible to get an increase in recycling. Panel (a) shows the result of a reduction in total demand for aluminum cans. This could come about through, for example, a shift to another type of container (glass, paper) or an overall reduction in consumption of whatever the cans contain. The demand curve is pictured as moving back from D_1 to D_2. This reduces total can production from q1 to q_3, while leaving unchanged the production of recycled cans at q_2, thus increasing the recycling ratio. This is a revealing result. The recycling ratio was increased simply by decreasing total can output, without any direct intervention in the recycling process. This is because of the way two supply sources (virgin and recycled) relate to one another. When overall production shifts, the adjustment is done entirely on the virgin supply side.

Panel (b) shows the effect of investing in the recycling industry. This lowers the cost of one or more of the recycling functions (collecting, transporting, reprocessing,

Figure (16)

Ways of Increasing the Recycling Ratio



remanufacturing), and is pictured by a rightward shift in S_R from S^0_R S^1_R. This lowers the cost of producing any given

amount of recycled cans, although the curve still slopes upward. Total can output at q_1 is unaffected, but recycled output increases from q_2 to q_3, and so the recycling ratio increases.

Panel (c) shows the effect of lifting the cost of virgin materials. The primary motivation for increasing recycling is to reduce the use virgin materials, because of the environmental benefits this produce directly and because a smaller number of cans will be disposed of in the future. Suppose a tax were put on virgin materials, making them more expensive to the producers of cans. In effect this lifts the S_V line upward by the amount of the tax. This attacks the problem from both sides : Total can production drops from q_1 to q_3, and the output of recycled cans increases from q_2 to q_4.

Which of these approaches is likely to be the most effective? Two factors are involved here: the shape of the functions themselves, and the ease with which they can be shifted. Consider the S_R function. Other things equal, the flatter this function, the greater impact will there be from a change like a tax on virgin materials; see panel (c). If the capacity of the present recycling sector tends to be fixed and inflexible, the function will be steep. If it is easy for the existing aluminum can recycling sector to expand or

contract its output, given its present condition in terms of factors like the number of plants or the technology in use, the S_R function will be relatively flat. A rightward shift of S_R in panel (b) can occur because of investment in additional recycling plants or adoption of better recycling technology, or a combination of both. The development of better recycling technology is, of course, a major pursuit in most modern economies. For aluminum cans and plastic soda bottles, new machines have mechanized the deposit return function.

Although this simple model shows some basic relation, it cannot show how rapidly situations can change in the real world. Demand can shift because of demographic and economic changes; cost curves can change because technological factors underlying production, especially from recycled sources, will evolve, sometimes rapidly. In addition, macroeconomic factors and international trade developments can have substantial effects on resource prices and therefore on markets like the one analyzed in the model.

4- Energy Resources:

Energy has two important dimensions. It is a critical input as a power source. This is specially true of modern, industrialized economies whose service and manufacturing sectors are based on huge systems of non-human power supply. It is also true of developing countries that are tied more closely to basic sectors such as agriculture. All people are dependent on incoming solar energy.

The other important dimension of energy use is as a source of pollution. For example, energy conversion the burning of fossil fuels creates residuals that normally find their way into the environment. Carbon dioxide emissions from fossil fuel burning are implicated in global meteorological changes and the increase in surface temperatures that may result energy emissions from the conversion of nuclear fuels have been shown to have negative impacts on the health of humans.

These two sides of the energy resource are closely connected. If the amount of the energy taken into a system for power purposes declines, then the energy-related emissions coming out the end of the system will decline, other things being equal. A shift from one type of energy source

to another, coal to natural gas, will also change the environmental impacts of energy.

The Political Economy of Energy Markets:

Petroleum refining and distribution are similarly dominated by a relatively small number of very large firms. What is more, these are essentially the same large companies that dominate the production side, these companies, in other words, are vertically integrated within the petroleum industry. Many of these companies are also horizontally integrated, they operate, often through companies they have purchased in other industries. Prices in the latter 1990s hit very low levels, and this tended to encourage further concentration of the industry. Mobil and Exxon have recently merged, and other mergers are being explored.

The actions by OPEC in the 1970s were political. The price increases of the time were not related to any fundamental changes in world petroleum supplies. Nevertheless, they served to focus people's attention on the basic adequacy question: When are the world's petroleum supplies going to be exhausted, and is this close enough in time that we need to start worrying about it now?

Energy adequacy questions can be usually broken into three categories, based on the length of time that is considered:

1- In the short run (10 to 20 years) how much should we try to switch to fuels other than petroleum? Solar power is cheaper but still expensive relative to fossil fuels and will require more research and development before it becomes viable alternative for the huge amounts of base load power that the system consumes. Natural gas appears to be a very available substitute at the present time.

2- In the intermediate run (20 to 50 years) over the last several decades new discoveries have added to these supplies (North Sea & Alaska), but these may have led us into a false sense of optimism about our ability to continue to make new discoveries in the future.

3- In the long run (50 to 100 years) the question is how to make a transition to a non-petroleum based energy system. At one time nuclear power was thought to be the ultimate technology for the future and some countries have indeed invested heavily in nuclear system. At the present time the important question is not which particular energy form should be adopted for the very

long run? But how the search should be recognized? Can the petroleum industry be relied upon to make the correct decision about very long run energy issues; is there a role for public research and development?

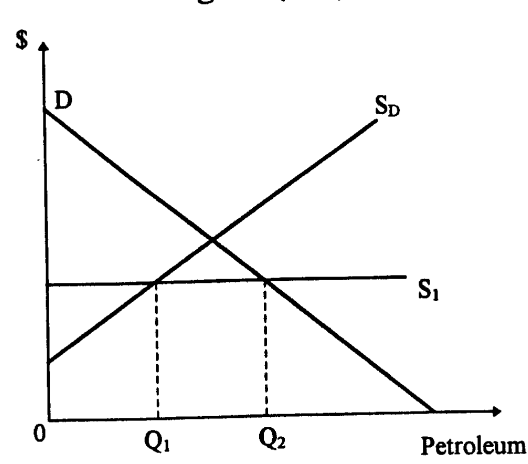
The Economics of Energy Self-sufficiency:

In the early days of petroleum use, domestic sources were sufficient to meet demand. But in the latter half of the twentieth century with the boom in automobile transportation, foreign sources have become much more important. The OPEC imports of the 1970s seemed to decline, but in recent years imports have again started to increase.

Consider the following figure:



Figure (17)



The aggregate demand for petroleum is labeled D, domestic supply is labeled S_D, and import supply is labeled S_I. Note that domestic supply is upward-sloping, while import supply is flat. Domestically, most petroleum deposits have been developed and additional national production can be produced only at higher prices. On the import side, the assumption is that there is a going world price and that additional supplies could in fact be obtained at this price. Total quantity consumed is Q_1, while Q_2 is the quantity produced from domestic sources. Thus imports are equal to $(Q_1 - Q_2)$ and the import dependency ratio (the proportion of total consumption imported) is $(Q_1 - Q_2) / Q_1$. Note that the world price establishes the domestic price. If demand were to shift right or left, the changes in quantity would occur in imports, not in domestic production.

There are in this simple model only three ways of decreasing the import dependency ratio:

1- Increase the world price. Since this is a world price and not one set domestically, it can only be changed by other means such as an important duty that effectively increases the price to importers. This would shift S_1 upward lowering total consumption Q_1 and increasing domestic output Q_2.

2 - Increase domestic supply, in effect shifting the S_D curve to the right. This leaves total consumption unchanged but would increase domestic production, thus cutting the import ratio.

3- Shift demand curve backward, by pursuing a strategy of energy conservation. This would reduce total consumption but not domestic production, thus lowering the import ratio.

If demand is relatively price-inelastic, then import tariffs will have little impact on overall consumption, so all of the adjustment will have to come via changes in domestic supply. If SD is relatively inelastic also, the import dependency ratio will be little affected by tariffs on imports.

One way that countries have sometimes sought to insulate themselves from unstable world markets, or future-run price increases, is through advance purchase and storage (sometimes called buffer stocks). Materials put into storage can be taken out and added to market supplies in times of high prices, thereby putting downward pressure on these prices. The economics of buffer stocks is reasonably straight forward, but of course there are many uncertainties. A major factor is how large the stocks should be, the higher the stocks, the greater the ability to protect the do-

mestic market from international price stocks. But also the larger the stocks, the greater the cost.

Energy Conservation:

Economic growth in the developed world has been accompanied in general by the copious or the increasing consumption of energy. Events of the 1970s showed that in this type of world, energy conservation is a very viable alternative given the right incentives. Since prices have decreased, however, one hears less of this concept. For an energy importing country like the United States, energy conversation has important implications for national security. Energy conservation is important also in the battle against global warming.

What is energy conservation?

Consider the following expression:

$$\text{Total energy consumed} = \text{Total number of people} \times \text{Income per person} \times \text{Energy consumption per dollar of income}$$

Where:

$$\text{Energy use per person} = \text{Income per person} \times \text{Energy consumption per dollar of income}$$

So,

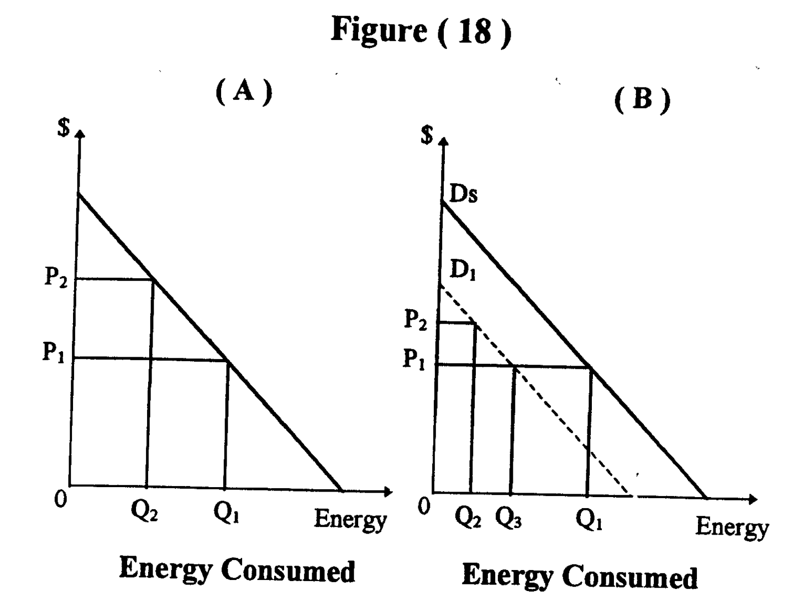
$$\text{Total energy consumed} = \text{Total number of people} \times \text{Energy use per person}$$

Total energy use is clearly tied to total population. But for a given population, energy use is also related to income. The reduction in energy demand results from an economic recession and falling incomes, although it reduces energy consumption, is not energy conservation, because consumption will increase again as soon as economic growth is re-established.

There are essentially two ways of achieving energy conservation, which are depicted in the following figure (Figure 18).

The Demand curves in the two panels show expected aggregate demand functions for energy in some future year, say 5 years from today. Panel (A) shows the impact of an increase in the price of energy. Suppose the current energy price is equal to P_1 . If this price persists, then the quantity demanded of energy in our target year will be Q_1. But if we have an increase in price for some reasons, the quantity demanded of energy in that period will only be Q_2 units. In this case, energy conservation consists of a price-induced movement up along a given energy demand function.

Figure (18)



To some extent this is what happened in the 1970s in response to increases in the price of petroleum. In the early days of the oil embargo in the fall of 1973, many observers took the position that this type of energy conservation was essentially impossible that the economy need and required large amounts of energy, thus consumers in 1973 found numerous ways to conserve energy in response to the price increases of the time (like turning off lights, running air conditioners a little lower, and going to the grocery store fewer times of weak).

How much consumption will decrease in response to price increases depends in large part on the slope of demand curve. For a given P and Q, the steeper the slope, the less responsive quantity is to price and the less steep the slope, the more responsive. We can think of the aggregate demand curve for energy as being built up from all the individual demand curves in the economy of households, business, public agencies, and so on. The reduction in aggregate consumption is a result of all individuals adjustments made throughout the economy.

Panel (B) of Figure (18) shows another way of achieving energy conservation, in this case the price increase to P_2 provides an incentive for technological developments that change energy consumption patterns: a shift to more efficient equipment, machinery, and building methods. What these changes do is actually shift the expected demand function back. Instead of the demand curve at D_S years hence, it actually occurs at the level indicated by the dashed demand curve D_1. At the higher price P_2, consumption is now only Q_2, and should price drop back to the previous level. With D_1 and P_1, consumption would be at Q_3, which is still less than the original level of Q_1.

The energy conservation depicted in panel (B) is more deeply rooted and structural than that of panel (A). It

is conservation that may persist in the long run, even if energy prices were to return to previous levels.

Economic Issues in Electricity Deregulation:

The energy sector is so important that it has always attracted public attention and political oversight. Major parts of the sector have at times been to public regulations but just as in many other important sectors (airlines, trucking), the contemporary move is toward deregulation. Many years ago the natural gas sector was tightly regulated, especially through controls on prices.

The electric power system is extremely complicated, both technically and organizationally. Electricity is generated in a wide variety of power plants. Large base load plants fried by nuclear, coal, or petroleum. Electricity is transported long distances over a net work of high-voltage transmission lines.

Technological developments in electric generation have helped push the system toward more competition. Competition is not an objective desired for its own sake, but for the positive economic effects it is expected to have:

1- Competing firms will be motivated to produce at the lowest possible cost and sell their electricity at the

lowest possible price, if they do not do so, other competitions may take their markets.

2- Competing firms will have the incentive to search for new, cost-reducing technological improvements in electricity generation and transportation.

3- Consumers will have wider choices which they may pursue to satisfy their own preferences.

Electricity deregulation also has implications for environmental matters. The overall impact of deregulation is supposed to be a substantial reduction in energy prices to consumers, This will lead to increases in the quantity of electricity consumed, other things being equal. This implies either developing new generating capacity or using the existing system at a higher rate.

Summary:

Energy is a major resource underlying economic growth in the developed world. Energy prices were declining until the decade of the 1970s, at which time they rose dramatically for political reasons. Since then, prices have gone back down, in some cases reaching levels today that are below those of the 1960s. Questions of future energy adequacy are difficult to answer. On the one hand, people have been predicting energy shortages almost continuously

over the last century. On the other hand, discovery, development, and technical change have continued so dramatically that shortages have not occurred. Some predictors today are that petroleum will begin to tighten substantially over the next two decades.

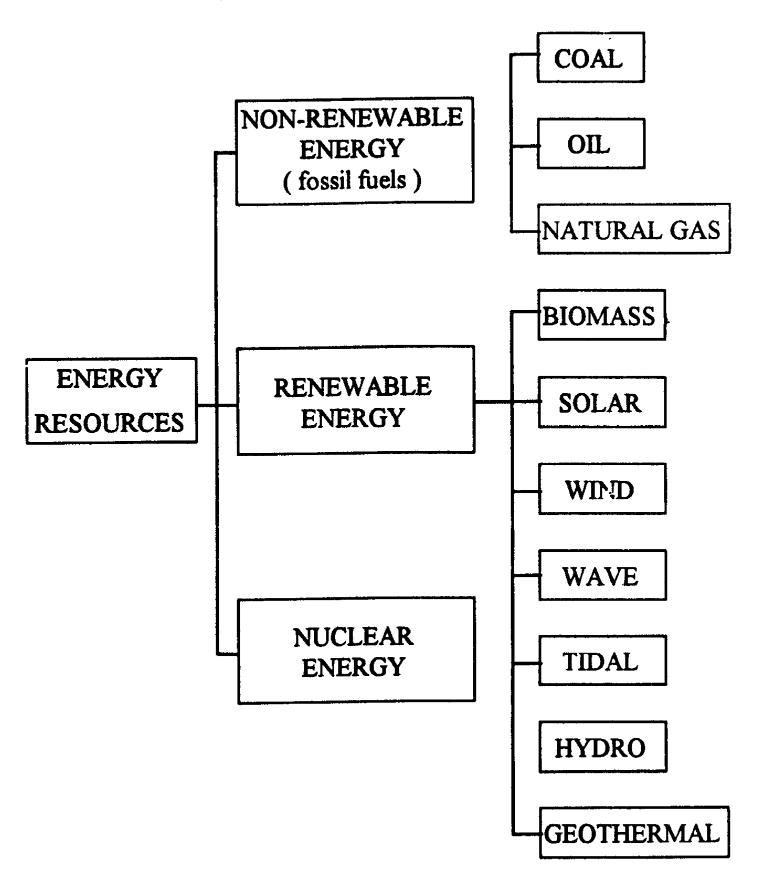
Classification of Energy Resources:

An important distinction can be made between primary and secondary energy sources. With the exception of nuclear power, all the forms of energy shown in figure (17) are primary energy sources in that they can be used directly to produce heat or to drive machinery. However, it is often convenient to convert them into the secondary fuels of gas and electricity. Indeed, future of some sources, such as wave, tidal, nuclear and hydropower, is almost wholly dependent on the economic viability of electricity generation. primary electricity is defined as geothermal, hydro, nuclear, solar, tidal, wind and wave, not that derived from the burning of fossil fuels. Such a distinction between primary and secondary energy should not be confused with the use of the term' primary energy' in, for example, the BP Statistical Review of World Energy where it denotes commercially traded fuels (oil, natural gas, coal, nuclear energy and hydroelectric power) as distinct from fuels such

as wood, peat and animal waste which are unreliably documented in terms of consumption statistics.

Figure (19)

Categories of Energy Resources



A more important distinction is made between renewable and non-renewable energy resources. On a geological time scale all our energy resources are either renewable or continuously available through the operation of the geophysical processes driven by incoming solar radiation, but given the rapidity with which fossil fuels are being consumed, relative to their over millions of years, the distinction between renewable and non-renewable energy resources is worth preserving. The non-renewable energy resources are the carbon and hydrocarbon fossil fuels of coal, oil and natural gas. Renewable energy is derived from a variety of flow resources categorized here as biomass that can be depleted, sustained or increased by human activity, and from continuous resources that are available irrespective of human activity yet can be modified to suit our needs. Such sources include solar, wind, wave, hydro and tidal power, as well as geothermal energy derived from the heat of the Earth.

There are various ways of measuring stored energy and the output of power. Any comparison of statistics through time or between countries is hampered by the use of different values (for example, Kilo-calories or British Thermal Units, watts or horsepower) and the need for complex conversion factors.

Conventional Non-renewable Energy Resources:

Carbon and hydrocarbon fossil fuels are formed from the decomposition of organic materials buried millions of years ago and transformed by heat and pressure into coal, oil and natural gas. Depending on the degree of compaction and heating, coal may occur as lignite, bituminous coal or anthracite in seams up to tens of meters thick. Lignite or brown coal is of low grade, containing about 70 per cent carbon. With a high percentage of moisture it gives of most smoke, and although it burns readily it has a low heating power. It is used mostly to generate electricity, notably in the Silesian coal belt of eastern Europe where it contributes seriously to atmospheric pollution. Bituminous coal is of medium grade, containing about 80 per cent carbon. It is black with a high heating power, and breaks up into cubical blocks which makes it suited to a variety of purposes, e.g. electricity generation, domestic heating and coke production. Anthracite is black, hard and brittle, and contains up to 98 per cent carbon. It burns slowly, almost without smoke, and with the highest heating power of all types of coal is favored for domestic heating.

Oil or crude petroleum is a mineral oil consisting of a mixture of hydrocarbons of natural origin, yellow to black in color, of variable specific gravity and viscosity,

including crude mineral oils extracted from bituminous minerals (shale, bituminous sand, etc.). Oil is usually found beneath impermeable cap rock and above a lower dome of sedimentary rock. In some cases, compaction will cause the oil to move to the surface where the lighter hydrocarbons disperse or evaporate, leaving the residual hydrocarbons to form tar sands. Such sources have been used for millennia but the modern oil industry can be said to date from 1857 when the first commercial wells were drilled in Romania, though by the end of that decade production was dwarfed by the output from Pennsylvania, most of which was refined into kerosene for use as a lighting fuel.

Natural gas is a mixture of hydrocarbon compounds and small quantities of non-hydrocarbons existing in the gaseous phase, or in solu-tion with oil in natural underground reservoirs. It is composed mainly of methane but includes natural gas liquids such as butane and propane that liquefy at normal atmospheric pressure, and are used widely in bottled form. Until recently, the greater part of the natural gas liberated in the production of crude oil was flared off at the well head. This has been both a massive waste of energy and a significant contributor to atmospheric pollution, even allowing for natural gas being the highest-quality and cleanest-burning fossil fuel. These

qualities together with the low cost of transportation and storage once a network of pipelines has been established make natural gas particularly attractive for space heating systems, and increasingly for electricity generation.

Fossil fuels possess many advantages. They are readily accessible and easy to use by means of technologies that are well understood and have been refined over more than a century to be safer, more cost-efficient in production and use, and generally more environmentally sympathetic, at least against the standards of the past. The quest to exploit oil reserves in every-more hostile environments remains at the forefront of technical endeavor. Fossil fuels have a high energy content, oil in particular. All fossil fuels are important feed-stocks for other industries. As coals differ in their moisture, carbon and volatile gases content so does their cooking ability and potential for providing heat energy and by-products such as ammonium sulphate, tar, crude oils and gas. Both oil and natural gas are raw materials for petrochemical industries producing a vast range of products, including explosives, fertilizers, pesticides, plastic, synthetic fibers, paints and detergents. A particular advantage of oil is its fluidity at ash stages in its exploitation. Oil that is not free-flowing under natural pressure can be pumped to the surface

without much difficulty. However, only about one-third of a typical oil reservoir can be pumped out, even after secondary recovery procedures involving, the injection of water to force out further quantities of oil. Enhanced oil recovery methods are more complex and not always cost-effective. Oil is also a fluid as it passes through processing into final uses. As a liquid it is easily handled and can be transported economically by pipeline or super-tanker. Loading and discharge cause it no damage in structure, unlike coal, and it is easily stored. Compared to coal, the cost of movement is low, it is a more easily controlled fuel in combustion, it burns more cleanly and produces less carbon dioxide, and leaves no ash. Natural gas is cleaner still and easy to use, but it is more costly to transport by liquefied natural-gas tanker than crude oil.

The disadvantages of fossil fuels are primarily environmental. Fossil fuels are, of course, a finite resource. The reserves of coal are vast, not so for oil and natural gas. Even allowing for new discoveries, advanced by higher prices in response to future scarcity, oil and gas are unlikely to play as important a part in energy use a hundred years from now.

Renewable Energy Resources:

Energy obtained from sources other than nuclear power or conven-tional fossil fuels is commonly referred to as alternative energy, not least because the various sources, though renewable or continuously available, contribute only slightly to total world energy consumption. The term new renewable energy has been coined to cover solar, wind, geothermal, wave, tidal, small-scale hydro and modern biomass sources as distinct from traditional biomass derived from fuel-wood, crop wastes and animal dung, and larger-scale hydroelectric schemes on the grounds that there is widespread concern about the environmental impacts of large hydro, and grave doubts about the sustainability of traditional biomass in some regions of the world.

Solar energy as defined at the beginning of this chapter is the driving force of all the renewable energy sources apart from tidal power and geothermal energy. In a more direct sense, solar energy generally involves capturing the sun's rays in order to warm buildings or heat water. On a small scale, flat plate solar collectors have proved highly effective in domestic water heating systems in sunny climates. The use of focusing collectors based on a series of mirrors producing sufficient heat to raise steam

and generate electricity has been employed in the French Pyrenees and California, but most power plants remain largely experimental. Other specialist applications include the use of photovoltaic (PV) cells to operate pocket calculators and domestic electrical equipment, and to power satellite equipment in space.

The power of the wind may be used to drive machinery as it has done for centuries, for example, windmills and wind-pumps, and to generate electricity. Most wind turbines have revolving blades, sometimes as much as 100 m in diameter. These drive generators and provide electricity either for local use or to feed into a grid. Electricity generated from the stored kinetic energy contained in ocean waves, the effect of wind blowing over the sea, has yet to move beyond the experimental prototype stage, but the potential if not the economic feasibility of wave power around our coasts is considerable. If harnessing the power of the waves has to date defeated human ingenuity, flowing water has long been utilized to drive machinery. Only with the coming of the fossil-fuel based technologies that raised the pace of the Industrial Revolution did water power recede in importance. In the twentieth century, the contribution of water power to total energy consumption has increased with the development of

hydroelectric power in which a fall or head of water is used to drive electricity generating turbines. Tidal power stems from the gravitational forces of the moon, and is similar in principle to hydroelectric power in that the head of water formed behind a barrage between high and low tides is used to drive turbines to generate electricity.

Biomass energy is produced from renewable sources of plant and animal residues. They may be burnt as solid fuels or converted to gaseous or liquid forms. Wood and charcoal are widely used in developing countries for heating and cooking, as are crop residues and dried animal excrement in areas with limited tree cover. These sources have a low energy content compared to fossil fuels due to their high moisture content, a problem compounded by their generally inefficient use in open hearths. In some countries, plant residues from sugar cane (bagasse) and rice husks are now burnt more efficiently in industrial furnaces to generate electricity. Also in this category are the products of decomposition from organic wastes, commonly called biogas, primarily methane gas (CH_4). Methane, collected from small-scale biogas digesters, has become widely used in rural Chinese households. This gas is also produced naturally when domestic waste is dumped in landfill sites and allowed to decompose, at first in the

presence of oxygen but mainly anaerobically. Liquid fuels can be produced from alcohol formed during the fermentation of plant sugars. Ethanol (ethyl alcohol) is mainly produced from sugar and grain crops and can be used in a mixture with petrol (gasoline) as an automotive fuel or in pure form with modified engines.

Geothermal power is derived from two principal sources. Most developments are where the Earth's crust is thin or fractured as in volcanic zones such as North Island, New Zealand, and Iceland Steam or hot water can be tapped from bore-holes or at surface vents, and used either directly for heating buildings and greenhouses or to generate electricity. Distinct from these wet-rock geothermal sources is hot dry-rock geothermal energy where the heat of rocks several thousand meters below the surface is utilized. Two bore-holes are drilled into the hot dry rocks. Water is forced down one and through cracks created between the two bore-holes into the second up which it rises picking up heat creating steam which can then be harnessed to generate electricity. Dry heat reservoirs are rare, but examples can be found in Italy, Japan and California.

The principle advantage of alternative or renewable energy sources is that they are renewable, though in the

case of fuel-wood the rate of use in many developing countries is far from sustainable. In many locations, the environmental degradation caused by such wanton destruction of trees has been so severe that the prospect of renewal is remote. For isolated rural communities and quite large parts of many developing countries where connection to national grids fueled by conventional power sources would be prohibitively expensive, the development of wind, hydro or solar power may be the only feasible alternatives. The disadvantages of renewable hinge upon unfavorable comparison with fossil fuels. A very much greater weight of biomass than coal or oil is needed to produce a given quantity of energy. Many sources pose problems for energy storage, and for matching supply to demand. Solar energy production is dependent on sunshine, and wind energy is significantly affected by topography and weather, with seasonal, daily and hourly variations. In many developing countries where different energy sources feed into a national grid, hydroelectric power is especially valued to meet surges in demand. The seasonal flow of rivers, however, can reduce the conversion capacity of hydroelectric schemes, with particularly serious consequences where it forms the base

oad. Although most renewables are non-polluting, their promotion is not without some environmental concern.

Nuclear Energy:

There is some value in placing nuclear energy in a separate category. At present, all commercial nuclear power stations use fission reactors in which the atoms of non-renewable minerals such as uranium-235 and plutonium-239 are split by neutrons thus releasing energy mainly in the form of heat. As a fossil fuel, the uranium required for the present generation of nuclear power stations may last no longer than oil, a concern that has driven research into fast-breeder reactors where the uranium is used more efficiently, thus extending the life of known resources. The vast amount of global investment into research and development of fast-breeder reactors has so far failed to produce a safe and economic design. The development of fusion reactors whose energy is derived from the fusion of two atoms could provide energy without any underlying fuel supply problems but feasibility, let alone the commercial prospects, are not encouraging.

When nuclear energy was developed for civil use in the 1950s it was heralded as clean, safe and cheap. As concerns grew over the consequences of the release of

radioactive materials into the environment following a series of reactor accidents or incidents in the 1970s and 1980s, the nuclear industry continued to stress the fundamentally clean nature of nuclear electricity generation. Compared to the burning of conventional fossil fuels in thermal power stations which produce large amounts of carbon dioxide, the main contributor to green-house gases, nuclear energy is indeed clean, but public confidence has been shaken and governments have been alarmed by the growing evidence of the higher-than-expected costs of electricity generation, even before the costs of safe disposal of nuclear wastes and the decommissioning of redundant power plants are taken into account.

Patterns of Energy Consumption:

Factors Affecting Energy Demand:

How much energy is used and what form it takes depends ultimately on our demand for the goods and services which its use provides. The level of energy demand is affected by four main factors: its price; the level of economic activity; the rate of population growth; and the nature of the environment.

Following the previous discussion on how the price mechanism helps to mitigate scarcity, one would expect energy demand to rise or fall with every downward or upward shift in price, reflecting the prevailing supply position. Between 1980 and 1982 oil price rises did lead to a 17 per cent fall in world demand, but there has been a very much slower response to the lower prices that have prevailed since 1986. indeed, the 1979 peak in world oil consumption was not matched until 1992. In North America and western Europe, annual oil consumption remains below the peak levels recorded in 1978 (976 million tones) and 1973 (736 million tones) respectively. In large measures this reflects the loss of price competitiveness compared to other energy sources, and illustrates that the substitution of one source for another in the interests of energy security and diversification can have long-term consequences for producers.

Economies with expanding industrial output, trade and consump-tion will make more substantial demands on energy resources than those in recession. Much too will depend on the structure of a country's economy, that is, the relative importance of different sectors of the economy to the generation of gross domestic product (the value of goods and services produced by an economy). The greater

the extent of manufacturing, particularly primary processing, the more intensive will be the energy use. Energy intensity can be measured as the tones of oil equivalent (toe) consumed per thousand dollars of GDP. Until relatively recently, it could be demonstrated that energy intensity increased with GDP, emphasizing the substantial gap between developed and developing countries, but between 1980 and 1994 energy intensities in the USA fell from 0.67 to 0.31 toe per $ 1000 GDP, and in the UK from 0.37 to 0.22. This reflects the substantial shift in most mature industrial countries to an economic structure dominated by service sector activities as well as an improving efficiency in energy use. The generally poorer energy efficiency in many developing countries stemming from the use of obsolete or badly maintained machinery can account for some developing countries having higher energy intensities than those in the west despite their much lower levels of GDP.

Population growth is likely to increase energy demand, though much depends on the income or spending power of the population. Urbanization too is likely to increase consumption of commercial fuels, especially in developing countries with the transition from a rural way of life still dependent on renewable energy sources such as

biomass. The physical environment in its widest sense is an important influence on energy consumption. Just as a warm climate significantly reduces the human minimum daily calorific requirement, so does the temperature regime influence energy demand. In tropical zones, space heating needs are much reduced though the use of air conditioning is increasing energy consumption in both domestic and work areas, especially in the Middle East and southeast Asia. In mid and high latitudes, seasonal climatic variations are responsible for a marked imbalance in energy demand between summer and winter. This can place a considerable burden on energy supply managers if fuel stocks are to be regulated efficiently. It is also the case that the geographical size and shape of a country together with distribution of its population and economic activities will have a bearing on energy use. The energy demands of transportation systems are likely to be greater in large or elongated countries than in small or compact ones. The transportation sector consumes about one-fifth of the commercial energy produced in the world, with more than 90 percent being derived from petroleum products.

Energy Demand in Historical Perspective:

There has been a rapid increase in energy consumption over the past two hundred years. Prior to the

Industrial Revolution energy demands were largely confined to local renewable sources, notably timber, and the power of the wind and running water to move machinery. Transportation and agriculture relied upon animals to move people, goods and farm implements. Lighting depended upon the burning of vegetable and animal oils. As the nineteenth century progressed abundant deposits of coal were exploited to raise steam to power machinery. In time came the technology to utilize the great reserves of oil and natural gas. Within little more than a century energy consumption had shifted to a dependence on fossil fuels. The renewable or continuously available nature of most energy sources in pre-industrial times prevents us from making any realistic evaluation of levels of consumption prior to the modern era. Even now, it is difficult to measure the extent of energy demand beyond the commercially traded fuels.

Energy and The Environment:

At every stage in an energy chain connecting the production of primary energy to its end-use there is an environmental cost. Pollutants of various types are an inevitable consequence of the discovery, production, refinement, transportation and storage of fossil fuels prior to consumption. Renewable energy resources are much

less damaging to the environment but even photovoltaic cells, non-polluting in their use of incoming solar radiation, involve some pollution in their manufacture.

Energy Production and The Environment:

The production of energy has an adverse effect on terrestrial, aquatic and atmospheric environments. On land, the disruption may be no more than the visual intrusion of mine workings or oil wells, including the installation of pipelines and storage facilities, but even this has inevitable consequences for natural habitats and local communities. Decades of environmentally unregulated coal mining have resulted in land subsidence, scarred hillsides and massive waste dumps as well as the aquatic consequences of polluted streams and contaminated ground-water from acid mine drainage. The lesson for eastern Europe and the FSU, and indeed the developing world, from the US experience of the mistakes of the past is that unregulated coal mining in a free market economy can cause extremely serious environmental harm with attendant adverse social and economic impacts which cannot be effectively resolved without comprehensive and strict governmental regulation. The experience of state-controlled mining and power generation in the FSU amply demonstrates that

environmental harm is not confined to unregulated free market economies.

The impact is not confined to fossil fuels. The development of a hydroelectric scheme may require the damming of a river and the flooding of a large area with obvious consequences for flora and fauna, agricultural production and displaced populations. The Balbina dam in Brazil, for example, destroyed more than 2.300 km2 of primary forest, formed a lake of shallow stagnant water, flooded indigenous lands and caused deep social disruption in the area for only 80 MW of power, a third of installed capacity. Traditional biomass is renewable but all too often the harvesting of fuel-wood cannot be sustained, and leads to the destruction of tree cover, increasing the risk of soil erosion and deserti-fication. The burning of animal and crop wastes may be a rational response to a shortage of alternative fuels in many developing countries, but the smoke contributes to acute respiratory infections that cause an estimated 4 million deaths annually among infants and children, and uses resources that might otherwise have improved soil fertility and structure. Solar, wind and wave power all require a very large number of conversion devices (solar panels, windmills, etc.) to produce the same amount of electricity as conventional power stations. The

visual intrusion of wind farms or wave machines over a large area of land or coastal waters may not be tolerated where the amenity value of the landscape is highly regarded.

Fossil fuels are also major sources of aquatic pollution, notably through acid mine drainage, that is the seepage of sulphuric acid solu-tions from mines and waste dumps. There is evidence too that a major source of groundwater pollution in the USA is leakage from undergıound oil storage tanks. Transportation poses another threat, particularly to marine environments, as has all too often been the case with crude oil spillages from tanker accidents and deliberate discharges while cleaning ships bilges at sea. While the long-term impact of dramatic oil tanker collisions may be less serious than once thought, except perhaps in the most fragile ecosystems, the immediate consequences for marine life are devastating. The problems of hydroelectric schemes are not confined to those described above. There are many secondary effects of dam construction. Stream hydrology, the processes of erosion and sediment deposition, and river ecosystems are all significantly altered. Regulation of stream flows can be an advantage but the deposition of sediment behind dam walls can reduce reservoir capacity and seriously reduce an

expected 75 year operating life. Clear-water releases below the dam change the ecological balance, while the lack can lead to increased erosion. These effects may extend hundreds of kilometers downstream. The lack of sediment in flood waters and the consequent erosion of the Nile delta as a result of the Aswan Dam has led to saline penetration of coastal aquifers.

Although the burning of biomass and the release of methane contribute to atmospheric pollution, the use of fossil fuels, especially coal, in power generation is a major cause of acid rain and global warming. The continued use of lignite in east European power stations is a major source of pollution. Lignite has a high ash and sulphur content. Emissions of sulphur dioxide (SO_2), oxides of nitrogen (NO_x) and particulate are especially high, and have a clearly adverse effect on the health of people living in the area. Substantial quantities of these pollutants create a transboundary problem, being generated in one country and deposited in another. The most striking example of transboundary air pollution has been the spread of radiation to some 100 million people across northern Europe from the nuclear accident of Chernobyl in the western USSR (now Ukraine) in 1986.

Energy Consumption and The Environment:

An awareness that the consumption of fossil fuel can cause damage to the environment is often thought to be related to the rise of Green issues in the second half of the twentieth century. Whereas the geographical extent and severity of damage to the environment have reached crists proportions in many areas since the 1950s, there were many earlier incidents which show that the mining and burning of fossil fuels resulted in severe local environmental damage. As early as 1273 the English Parliament passed an act preventing the burning of coal in London. In 1306 a man was even executed for defying the law. An early account of urban air pollution in London can be gained from John Evelyn's book of 1661 entitled Fumifugium: Or the Inconvenience of Aer and Smoake Dissipated in which he wrote of the hellish and dismal cloude of sea coale (smong) caused by the burning of imported coal from Newcastle. Various attempts by Parliament to restrict pollution resulted in the 1750s in the passing of an Act preventing the burning of coal during the time Members sat in Parliament because of the noxious fumes that made life so intolerable for them. No concern was voiced for the poor Londoners forced to endure the pollution when Mps were away from London !

The industrialization of northwest Europe resulted in severe environmental damage much of which was accepted as an inevitable consequence of progress. Only occasionally were the environmental conditions recorded, one such example being the account by George Borrow of his journey through Wales in 1854 in which he described the industrialized landscape between Swansea and Neath as immense stacks of chimneys surrounded by grimy diabolical looking buildings, in the neighborhood of which were huge of cinders and black rubbish. From the chimneys... smoke was proceeding in volumes, choking the atmosphere all around. In 1863 the British Parliament passed the first comprehensive clean air Act which was intended to control the emissions of offensive gases, smoke, ash and grit. Impetus was given to the need to introduce legislation to improve the quality of the environment degraded by uncontrolled pollution from the burning and processing of fossil fuels and mineral resources by a succession of air pollution incidents that were responsible for the serious loss of human life. More recent legislation includes the UK Clean Air Act 1956 which established principles of legislation designed to reduce the impact of air pollution resulting from the consumption of energy resources. Similar legislation has been enacted

elsewhere in Europe and North America. In USA, for example, a Clean Air Act was passed in 1955, followed by a succession of laws designed to enhance the quality of the environment.

Global Warming:

One of the major concerns of the late twentieth century has been the debate, often controversial, involving almost every branch of science as well as the general public, on the likelihood of global warming and the associated subject of the accumulation of green-house gases. Our atmosphere comprises a mixture of gases of which carbon dioxide (CO_2) is an important element. Together with water vapor, it acts as an imperfect shield, slowing the loss of long-wave radiation from the Earth back into space. This effect was first recognized in 1896 by the Swedish chemist Arrhenius who coined the term green-house effect. Arrhenius also recognized that it was possible to alter the atmospheric content of CO_2 and thereby alter the transparency of the atmosphere. Without a natural green-house effect the average temperature of our planet would be approximately 30°C cooler than the current world average temperature of 14°C.

Increases in green-house gas emission are nowadays associated with the burning of fossil fuel for generation of energy. The primary green-house gas is CO_2 and since the early 1950s accurate records obtained from the Mauna Loa Observatory in Hawaii have shown that an average annual increase of atmospheric CO_2 of 1.8 parts per million (ppm) has occurred. This increase is equivalent to the addition of 3.3 billion tones to the total mass of carbon in the atmosphere in the form of CO_2. Despite some recent attempts to curb its increase it now appears probable that the pre-industrial CO_2 level of about 280 ppm will double by the year 2050. A large proportion of atmospheric CO_2 originates from fossil fuel electricity-generating stations. In Britain this source accounts for about 30 per cent of all CO_2 generated. There are many other green-house gases, notably methane, chorofluorocarbons (CFC) and various oxides of nitrogen (NO_x) .

The problem of how much to attribute global warming to the addition of green-house gases from anthropogenic impacts, as opposed to natural climatic change, is highly controversial and beyond the scope of this book. However, it is worth nothing that the repercussions of global warming are such that they will effect every living creature on this planet. If it can be

shown that by the profligate use of energy, human beings are contributing to this change then it would be prudent to examine ways of reducing the growth in energy consumption.

Nuclear Power and The Environment:

Nuclear power is one energy source notable for not contributing to green-house gases, but even members of the general public who do not sympathize openly with environmental and Green groups are hostile to the idea of replacing the use of fossil fuels with nuclear power in order to generate clean energy. The United Kingdom Atomic Energy Authority has presented a case to show that increasing the capacity of nuclear power generation could cut CO_2 emissions by 30 per cent by 2020. Nuclear Electric, the country's major provider of nuclear energy, claims that its present operations save the emission of 60 million tones of CO_2 and 840000 tones of SO_2 annually, compared with a conventional coal-fired plant.

While energy supplied by means of nuclear generation is undoubtedly clean in the sense that none of the chemical pollutants associated with combustion of coal, wood, oil and natural gas are produced, there are other environmental problems associated with nuclear power

generation. There is little doubt that the biggest questions that surrounded nuclear energy concern the following points :

- the safety of nuclear reactors during their working life;
- the safe disposal of nuclear wastes generated during the working life of nuclear power stations;
- the safe disposal, or decommissioning, of reactors at the end of their working lives.

While nuclear scientists have done their best to assure the general public of the safety of the nuclear industry, the occurrence of radiation leaks, the incidence of leukemia clusters around nuclear power stations and the horrific events at Three Mile Island in Pennsylvania in 1979 and at Chernobyl in 1986 have persuaded many the risks associated with the nuclear power industry outrun its advantages. The era of greatest enthusiasm for nuclear power occurred in the 1960s and early 1970s. Governments were assured by the nuclear industry that the problems associated with the disposal of wastes and the decommissioning of obsolete plant would be solved by future advances in technology. Whereas the legacy of most of the environmental blunders we cause can be remedied within the life-span of a human being the same is not true

for nuclear wastes. In addition to the extreme toxicity of radioactive wastes their life-span is measured in thousands of years and not in decades. The strength of radioactive materials decays exponentially, the half-life being the time taken for half the original amount of material to decay. The half-life of fission plutonium ranges from 6580 years for plutonium-240 to 379000 years for plutonium-242. Any accident which involves these radio-nuclides will contaminate the environment well into future.

In part, the public concern over the safe disposal of nuclear wastes has been caused by an inability of the nuclear industry to police itself. Deliberate dumping of intermediate and low-level packaged and liquid nuclear waste in the oceans occurred until 1970 when the USA ceased the practice. European countries ceased ocean dumping in 1982 but fears exist that some countries still persist with this method of disposal. The Baltic Sea is severely contaminated by dumping of former Soviet nuclear wastes and possibility also by deliberate abandonment of nuclear submarines. The London Dumping Conventions of 1975 and 1990 calculated that between 1946 and 1982, 46 petabecquerels were dumped at more than 50 sites, mainly in the North Atlantic and North Pacific Oceans.

Increasing The Role of Renewable Energy Resources:

The oil crisis of the early 1970s stimulated a belief that renewable energy resources could provide a significant proportion of future energy demand, thereby removing the threat of industrialized world being held to ransom by a small group of energy producers controlling a large proportion of energy exports. Such hopes have proved in vain mainly because the technology associated with renewables has not met with expectations, and because the supplies of conventional energy resources have been able to meet the growing demand for power. Most developed countries now specify a non-fossil fuel obligation (NFFO), that is, a proportion of the national energy supply that must be met from renewable resources. In the UK this is set at 10 percent, although only 2 percent is currently attained, whereas for countries with a high hydroelectricity capacity it can be much higher. By 1994, some 134 renewable energy projects (excluding hydro) totaling 251 MW had commenced generating in the UK, with a target of 1500 MW by 2000. Renewable energy is seen as providing clean, sustainable power sources and as such is much in favor with environmental bodies and governments alike. With a few exceptions, such sources are less cost-effective

than energy derived from fossil fuels, A CO_O tax on fossil fuels, however, might make electricity generation from renewables very much more attractive in an increasing number of countries.

Hydroelectric power (HEP) became a commercially viable source of energy in the 1890s. In the UK, all economically suitable sites have now been developed although worldwide only some 15 per cent of potential sites have been used. In spite of growing protests (many from environmentalists) over the kinds of issues identified before, HEP capacity is set to grow by some 2.5 - 3 per cent annum continuing a twenty-year trend. Some developing countries see HEP schemes as flaship projects, but as they are capital intensive they can divert financial resources from other more essential requirements. More appropriate might be small-scale mini and micro hydroplants often in remote mountainous areas such as western Nepal where they can bring immense benefit to societies which otherwise would have little chance of gaining access to electricity supplies.

Wind energy could provide a sizable energy output for many countries but to date only Denmark and The Netherlands, each with 1000 MW of production planned for 2000, appear to be committed to large-scale use of this

energy resource. The US target of between 4000 and 8000 MW (mainly in California) will make only a small contribution to energy supply. India aims to generate 5000 MW of energy from windfarms by 2000 but given the lack of clear priorities in its renewable energy programme this is unlikely to be achieved. In the UK the potential for wind power appears to be very high with up to 40 per cent of Europe's total realizable windfarm sites, yet construction plans have, paradoxically, met with fierce resistance from environmentalists and amenity groups on the grounds of unsightly intrusion into landscapes of high scenic value. In addition, noise from windmill blades and turbines, worries over the effect of electrical into the rotating blades have severely restricted the use of this energy resource. A suitably located wind turbine can currently produce 1.25 million kWh per year. In the UK it would require 2.400 such turbines in order to supply about 1 per cent of electricity consumption. Assuming windfarms with banks of up to 25 machines, between 95 and 120 would be required, covering a total of 250 km^2, or some 0.1 per cent of the total land area.

The total solar resource is over 10.000 times our current energy use but its low power density and its geographical and time variation represent major

challenges. Despite its appeal as the ultimate clean power source for humans, solar energy currently makes virtually no impact on commercial energy production, and is unlikely to contribute even 1 percent of total energy demand by 2020 unless research and development is greatly increased. Its use has been primarily confined to remote rural areas away from power lines. Photovoltaic cells can power telephones, radios and televisions, and supply some power for lighting if connected to a battery storage facility. In future its role may increase as architects are able to design buildings that can be successfully heated by passive solar capture as opposed to the current state-of-the-art-technology which relies on direct sunlight.

The future for biomass as a fuel lies not with its traditional uses, the highly inefficient burning of wood and animal waste for heating and cooking, which are likely to become increasingly unsustainable, but with the application of more advanced technologies. Already, some 13 per cent of Brazil's primary energy supply is derived from industrial processing of sugar-cane bagasse and ethanol. The Proalcool programme, aimed at decreasing Brazil's dependence on imported oil as the raw material for automotive power, now produces almost two-thirds of this sector's fuel needs. The potential for other countries to

develop ethanol programmes, and to use crop residues for the production of electricity is considerable, though competitiveness depends very largely on the price of alternatives and a political commitment to renewables. Charcoal is a major fuel in the Brazilian iron and steel industry, and again there is much potential for other countries to develop this resource. However, with more than two-thirds of Brazil's charcoal production coming from natural forests there is clearly a need for active reforestation to ensure a sustainable industry.

The utilization of biogas, mostly methane, produced by decomposing organic waste is not new. Both China and India have been at the forefront of developing small-scale biogas digesters or anaerobic fermentors, By 1991, some 1.4 million digesters had been installed in India, with an ambitious plan to complete 12 million by 2000. In developing countries, the potential for exploiting biogas produced in landfill sites is considerable. One ton of refuse can yield 400 cubic meters of gas, most originating during the first 15 years of dumping. If the methane can be collected and decontaminated, it can be burnt in a gas turbine connected to an alternator which produces electricity. When methane, which is an active greenhouse gas, is burnt it is converted to CO_2, a less aggressive

greenhouse gas, thus helping to slow global warming. The USA is the greatest user of landfill gases with about 70 commercial sites. Germany and the UK also use biogas for electricity generation and the potential for greater use in the latter country is very considerable as over 300 large landfill sites are available.

Tidal energy has largely been ignored as a power source despite it being inexhaustible and highly predictable. Coastlines with a tidal range greater than 4 m have the best energy potential. In England and Wales some eight estuaries could be harnessed to provide 20 per cent of current electricity demand. The technology for harnessing tidal power is largely proven as a result of the long-established 240 MW power station on the Rance Estuary in northern France. The main stumbling block is financial with a high capital cost per kWe of installed capacity. The proposed Severn Estuary barrage costing an estimated £ 10 billion, equivalent to six nuclear pressurized water reactor power stations, would produce the equivalent energy output of five such stations but have considerable environmental implications. If built, such a tidal power station could have a life of 120 years. The utilization of wave energy remains in the research and development stage. The much heralded Salter's Duck, a hinged flap that

rises and falls with the passage of waves and transfers the Kinetic wave energy to a generator appears the most promising device. Located some distance offshore, these devices may, one day, reach commercial viability but questions surround their durability in a corrosive and physically unpredictable environment.

Management Issues:

It is beyond the scope of this book to consider the vast range of management issues concerning energy production and consumption. Energy policy in particular has many diverse aspects that impinge on individuals, corporations and governments. Key objectives identified by different national governments reflect quite different energy systems and sociopolitical ideologies. Many may seem contradictory even within a country let alone between countries. They have included the desire to :

- increase energy production to meet domestic demand or to earn foreign exchange through trade;
- achieve sustainable development;
- regulate supply and demand in order to stabilize fuel prices and protect industrial and household consumers from undue price shocks;

- foster energy supply security to reduce vulnerability to politically insp-ired supply discontinuity;
- decrease dependence on any one source of energy;
- increase use efficiency in production; and

promote greater consumer use efficiency, and conserva-tion.



Chapter 9

Economics of Education

Human resources determine the character of economic and social development. Any country must be able to develop the skills and knowledge of its people and to utilize them effectively in the national economy.

Most developing countries believe that the rapid quantitative expansion of educational opportunities is the key to economic development. The more education, the more rapid the development. The educational systems of developing countries strongly influence and are influenced by the whole nature magnitude, and character of their development process.

The role of formal education is not limited to improving the knowledge and skills that enable individuals to function as economic change agents in their societies. Formal education also improves values, ideas, attitude, and aspiration which may or may not be in the nation's best developmental interests.

In this chapter, we explore the relationship between development and quantitative and qualitative educational

expansion. We begin with a review of education in developing countries, then we will review some basic concepts in the economics of education, including the determinants of the demand for education, and supply of education, and distinguish between private and social benefits and costs of investment in education. Next, we examine in details some issues to see if we can reach any conclusion about the relationship between education and various key components of the development process. We end with a review of an alternative policy options open to developing countries in their attempts to evolve an optimal educational system

1- Education in Developing Countries:

Many poor countries have invested huge sums of money in education. There are many reasons for this huge investment: First is to literate farmers with at least a primary education in order to be more productive and more responsive to new agricultural technologies. Second is to offer a specific training to secondary school graduates in order to perform technical and administrative functions in growing public and private sectors. Finally, university graduates with advanced training are needed to provide the professional and managerial expertise necessary for a modernized public and private sector.

In addition to the above reasons, parents in developing countries have realized that in an era of scarce skilled manpower, the better will be their chances of getting secure and well-paid jobs. More years of schooling have been perceived as only avenue of hope for poor children to escape from poverty.

Between 1960 and 1990, the total number of persons enrolled in the three main levels of education in Africa, Asia, and the Middle East, and the Latin America rose from 163 million to 440 million, an average increase of 5%. Although the largest part of this increase has been in primary education, it is in the secondary and university levels that the greatest proportionate increases have occurred, 12.7% and 14.5% per year, respectively. Nevertheless, primary enrollment still accounts for nearly 78% of the total developing countries school enrollments.

In terms of the proportion of children of school age actually attending school at the primary, secondary, and university levels, the differential between the developed and the developing countries and among the developing countries themselves is substantial. African countries lag behind at all levels, with only 67% of their primary school-aged children actually enrolled. Table (1) shows comparative data on enrollment ratios at the primary, secon-

dary, and higher educational levels for a selected group of low and middle income developing countries in 1965 and 1989. The remarkable increases in enrollment at both the primary and secondary levels are strikingly evident from this table.

The statistics of Table (1), however, can be very misleading. They tell us the proportion of school-age children and teenagers enrolled in primary, secondary, and higher educational institutions at a single point in time. They do not tell us how many of these students remain in school for a duration. In fact, one of the major educational problems of developing countries is the high percentage of students who dropout before completing a particular cycle. For example, in Latin America an estimated 6o out of every 100 students who enter primary school dropout before completion. In some Latin American countries, the primary school dropout rate is as high as 75 % . In Africa and Asia, the median dropout rate is approximately 54 % and 20 % , respectively. But the variation among countries has been wide, with dropout rates as high as 81 % in certain African nations and 64 % in certain Asian ones.

Table (1)

Enrollment Ratios in Selected developing countries (1965 - 1989)

Selected Countries	Numbers Enrolled as a percentage of Age Group					
Low - income Developing Countries	Primary		Secondary		University	
	1965	1989	1965	1989	1965	1989
Bangladesh	49	70	13	17	1	4
Ethiopia	11	38	2	15	0	1
Haiti	50	84	5	19	0	1
India	74	98	27	43	5	6
Serilanka	93	100	35	74	2	4
Tanzania	32	63	2	4	0	1
Middle - income Developing Countries	Primary		Secondary		University	
Colombia	84	100	17	52	3	14
Guatemala	50	79	8	21	2	9
Mexico	92	100	17	53	4	15
Philippines	100	100	41	73	19	28
South Korea	100	100	35	86	6	38
Thailand	78	86	14	26	2	16
Developed Countries	100	100	61	75	21	42

Source : United Nations Development Program, World Development Report, 1992 (New York : Oxford University Press, 1992) annex tab. 29.

At the secondary level, median dropout rates for entering students in 1975 were 38.7 % in Africa and 18 % in Latin America and Asia. In Europe, the rate was approximately 1.4 %. One consequence of this phenomenon, particularly for Africa, is the serious and growing problem of the secondary school dropout who joins the ranks of the educated unemployment.

One of the most problems facing the developing countries is called the Gender Gap, or the relationship between women and education. In fact, young females receive considerably less education than young males in almost every developing country. In 66 out of 108 countries, women's enrollment in primary and secondary education is lower than that of men by at least 10 percentage points. This educational Gender Gap is the greatest in the poorest countries and regionally in the Middle East and North Africa.

Table (2) provides data on female - male gaps in literacy, mean years of schooling, and enrollments for 10 developing countries in 1989 - 1990.

Table (2)

The Educational Gender Gap : Females as a percentage of males

Country	Adult Literacy	Mean years of schooling	Primary Enrollment	Secondary Enrollment	University Enrollment
Afghanistan	32	12	52	45	24
Algeria	65	18	85	77	44
Bangladesh	47	30	85	48	20
Egypt	54	42	79	78	52
India	55	34	97	56	45
Mexico	95	96	97	100	75
Morocco	62	36	69	71	58
Nigena	63	26	93	73	39
South Korea	94	61	100	96	49
Sudan	27	45	71	74	66
All DCs.	69	54	93	73	53

Source : op. cit, tab. 9.

For all developing countries taken together, the female literacy rate was 31 % lower than male literacy, women's mean yours of schooling were 46 % lower than men's and females' enrollment rates in primary, secondary, and higher schools were 7 %, 27 %, and 47 %, lower, respectively, than the corresponding male rate.

In our discussion of gender gap, we can address some important questions : Why is female education important? Is it simply a matter of equity? The answer is that there now exists empirical evidence that educational discrimination against women hinders economic development in addition to reinforcing social inequality.

Closing the educational gender gap by expanding educational opportunities for women is economically desirable for the following reasons:

1- Increasing women's education not only increases their productivity in the farm and in factory but also results in greater labor force participation, later marriage, lower fertility, and greatly improved child health.

2- The rate of return on women's education is higher than on men's education in most developing countries .

3- Improved child health and more educated mothers lead to multiplier effects on the quality of a nation's human resources for many generation to come .

4- Because women carry a burden of the poverty in the developing countries, any significant improvements

in their education can have an important impact on breaking the vicious cycle of poverty.

2- The Economic of Education and Employment:

Most of literature about education and economic development in general and education and employment in particular, revolves around two fundamental economic process :

1- The interaction between demand for education and supply of education in determining how many school places are provided .

2- The distinction between social and private benefits and costs of different levels of education and the implications of these differentials for educational investment strategy.

(A) Educational Demand and Supply:

The amount of schooling retained by an individual can be determined by demand and supply:

On the demand side:

The demand for education is a derived demand for high-wage employment opportunities in the modern sector.

This is because access to such jobs is largely determined by an individual's education. Most people (especially the poor) in less developing countries do not demand education for its economic benefits but simply because it is the only mean of securing modern-sector employment.

The demand for an education sufficient to qualify an individual for modern sector jobs is determined by the combined influence of the following four variables:

1- The wage or income differential (W_f):

It is the wage differential between jobs in the modern sector and those outside it (family farming, rural and urban self-employment, ect.), or we can call it as traditional sector. The greater the income differential between the modern and traditional sectors, the greater the demand for education. It means that the demand for education is positively related to the modern sector traditional sector wage differential, other things being equal.

2- The probability of success in financing modern-sector employment (P_s):

This factor indicates that an individual who successfully completes the necessary schooling for entry into the modern-sector labor market has a higher probability of getting well-paid urban job than someone who does not.

The probability of success in financing modern-sector employment is inversely related to the unemployment rate. As a result, the demand for education will be inversely related to the current unemployment rate, other things being equal.

3- The direct private cost of education (D_c):

We refer here to the current cost of financing a child's education. We would expect that the demand for education would be inversely related to direct costs. The higher the direct costs (school fees and associated fees), the lower the private demand for education, other things being equal. For poor people, direct costs represent a major burden and a real financial constraint.

4- The indirect or opportunity costs of education (Ic):

For each year, when the child continues his education, he forgoes the money income he could expect to earn or the output he could produce for the family farm. We would expect the relationship between indirect costs (opportunity costs) and demand for education to be inverse. That is, the greater the opportunity costs, the lower the demand for education.

So, we can write the demand function for education as follows:

$$D_E = f(W_f, P_s, D_c, I_c)$$

where :

D_E : Demand for education.

W_f : The wage or income differential (positive).

P_s : The probability of success in finding modern-sector employment (inverse).

D_c : The direct private cost of education (inverse).

I_c : The indirect or opportunity costs of education (inverse).

On the supply side:

The quantity of school places at the primary, secondary, and university levels is determined by political process and the level of aggregate private demand for education.

We can, for convenience, assume that the public supply of these places is fixed by the level of government educational expenditures.

(B) Social versus private benefits and costs:

In developing countries, the social costs of education increases rapidly as students climb the educational ladder.

The private costs of education increases more slowly. this widening gap between social and private costs is resulting from financing costly educational expansion at higher levels of education. As demands are generated progressively through the system, the social cost of accommodation grows much more rapidly than the places provided. more and more resources may be misallocated to educational expansion in terms of social costs, and the potential for creating new jobs will consequently diminish for lack of public financial resources.

The following figures illustrate these ideas:

Figure (1)

Social Costs

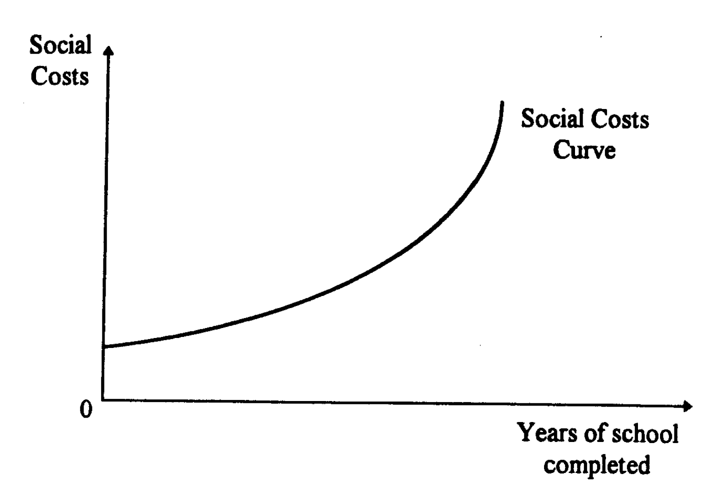
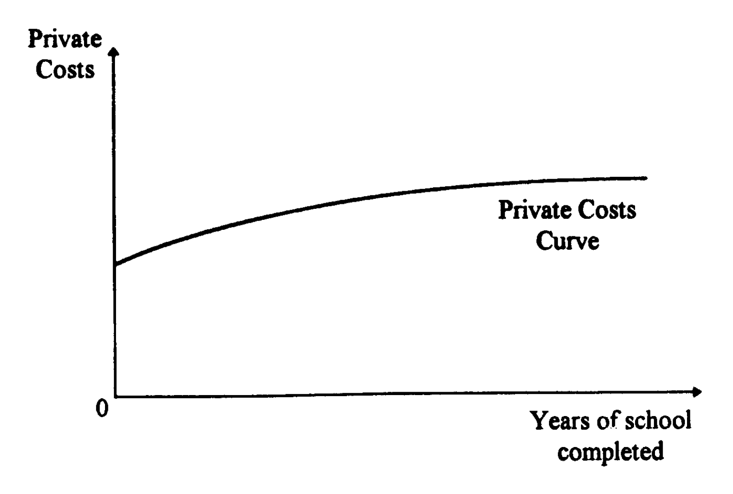


Figure (2)

Private Costs



The social benefits or returns rise sharply at first, reflecting the improved levels of productivity of small farmers and the self-employed that result from receipt of a basic education. There after, the marginal social benefits of additional years of schooling decline more rapidly. The private benefits or returns grow by increasing rate as a student completes more and more years of schooling. The following figures illustrate these ideas:

Figure (3)

Social benefits or returns

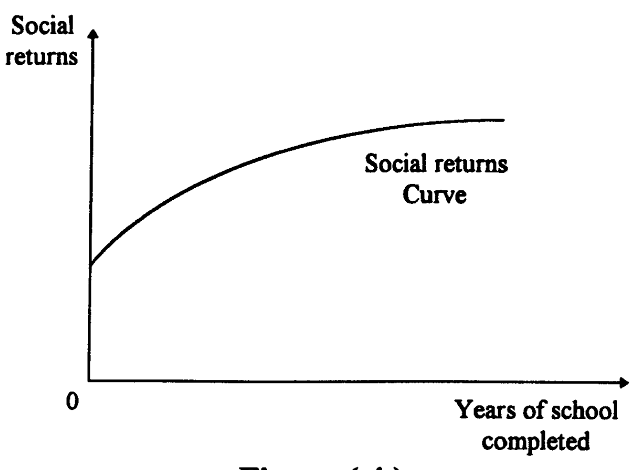
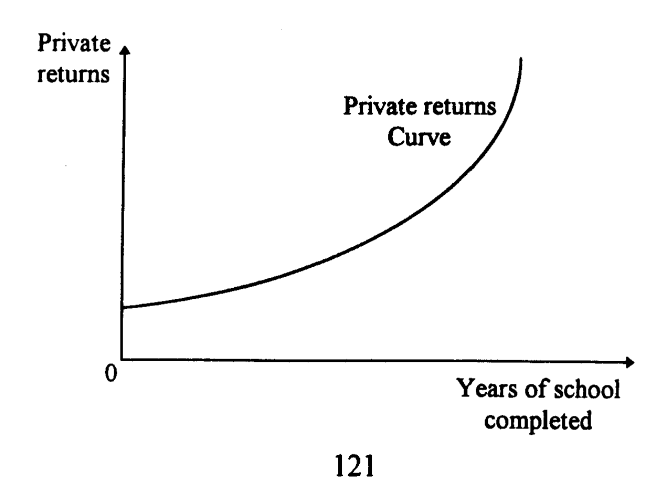


Figure (4)

Private benefits or returns

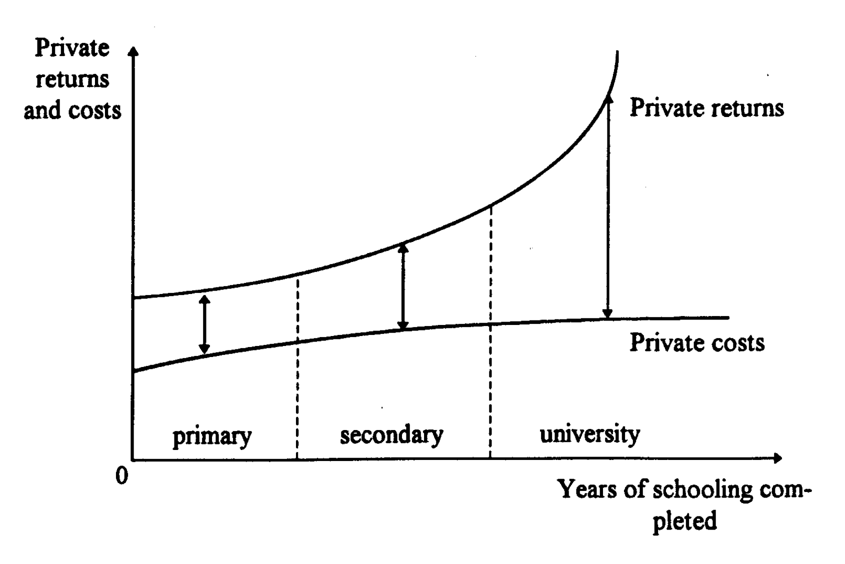


Private costs versus expected private returns:

In the following Figure (5), expected private returns and actual private costs are plotted against years of completed schooling. As a student completes more and more years of schooling, his expected private returns grow at a much faster rate than his private costs. To maximize the difference between expected benefits and costs, the optimal strategy for a student would be to secure as much schooling as possible.

Figure (5)

Private Costs Versus private returns



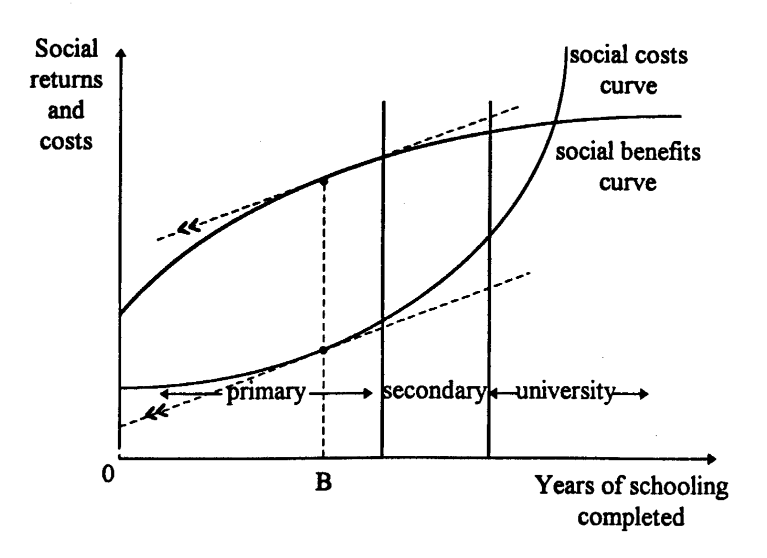
Social costs versus expected Social returns:

In the following Figure (6), Social costs and social returns are plotted against years of completed schooling. The social benefits curve rises sharply at first, and then declines more rapidly. By contrast, the social costs curve show a slow rate of growth for early years of schooling (Basic education) , and then a much more rapid growth for higher levels of education. This rapid increase in the marginal social costs of post primary education is the result of both the much more expensive capital and recurrent costs of higher education (Buildings and equipment) and, more important, of the fact that much post primary education in developing countries is heavily subsidized.

It follows from the following Figure (6) that the optimal strategy from a social view point, the one that maximizes the net social rate of returns to educational investment, would be one that focuses on providing all students with at least (B) years of schooling. Beyond (B) years, marginal social costs exceed marginal social benefits, so additional educational investment in new, higher level school places will yield a negative net social rate of return. The optimal social investment strategy may be to upgrade the quality of existing primary schools rather than to expand their quality.

Figure (6)

Social Benefits Versus Social returns



Chapter 10

Economics of Agriculture

We know that as people become prosperous they spend a lower proportion of their incomes on food. Generally the volume of food purchased does not change but the types of foodstuff alter and the expenditure on foodstuffs rises. Spending increases because the preferred foods (in the past at least) have been fatty, sugary and sold with a high degree of processing and packaging. Thus, most if not all of increases in spending on food are accounted for by intermediaries in the food chain rather than by farmers.

The demand for food and the derived demand for agricultural products is largely unresponsive to income and price increases. As life-styles and dietary habits change, there is substitution between types of food and the food industry is energetic in introducing new food products which will encourage consumers to switch brands and products. Even here, the impact at the raw material level is very limited, with sugars, starches and fats often simply being recast into different forms.

Demand for food farms (at the farm gate) is a reflection of retail demand. Since only 40 - 60 per cent of consumers' spending is received by farmers, and the remaining costs (distribution, packing, etc.) tend to not vary, the price and income elasticities of demand at the farm level are even lower than those in the shops.

The last point to note regarding demand relates to non-food products. The demand for wool (and timber, in so far as it can be regarded as a farm product) reflects the level of industrial demand. Prices tend to go up and down with the level of economic activity in the broader economy.

On the supply side the output of farm products suffers from variability in an unpredictable way from the influence of weather. Apart from this, farmers are limited in their ability to expand output in the short run because of the restrictions imposed by the biological nature of agricultural production. However, in the longer term they are generally able to respond to economic forces. There is a history of technological advances which spread through the industry with the inevitability of a treadmill, with the further repercussion of inexorable expansions of output.

Supply tends to increase with a ratchet-like progression. Given time, farmers respond to rising prices by

expanding their supply. Price falls have less effect on output because farmers are already committed to skills, to investments and to markets for particular production processes, implying lower elasticity when price falls.

1- Price Characteristics of Agriculture:

The consequences of the characteristics of demand and supply given above are that agriculture faces a particular set of price problems. These include annual price fluctuations, price cycles, and the long-term decline in farm product prices relative to the prices of the inputs that farmers use (the cost-price squeeze or the double squeeze).

Year-to-year price Variations:

The prices of many farm products are subject to year-to-year fluctuations caused by the weather's influence on the supply which faces a highly inelastic demand. Because of the inelastic nature of demand, years of high output result in a drop in prices which is greater than the rise in output ; consequently the revenue coming in to farmers from selling their product will be less in years of good yields than in poor yield years. As costs are to a large extent unaffected by weather, variations in revenue will result in disproportionately larger variations in income.

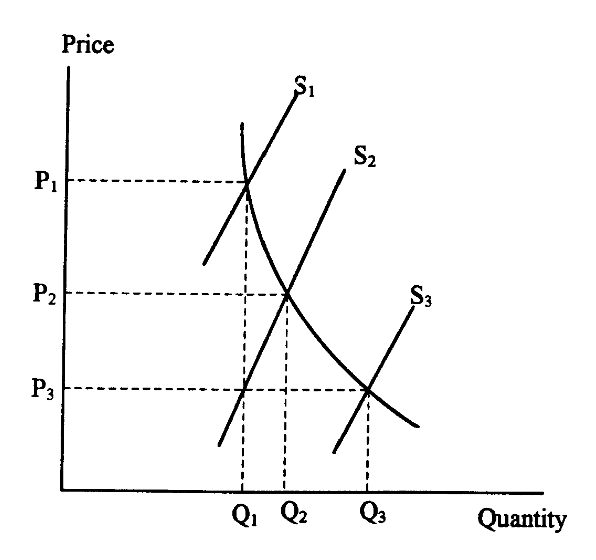
There is a tendency for farmers, faced with price changes which are beyond their power as individuals to affect and whose causes it is difficult to ascertain from the perspective of a single farm, to believe that this year's prices are a good guide to those that will exist next year. Consequently there will be a tendency for a year of high prices to be followed in the next year by a moderate expansion of supply and low prices to be marked by contraction, This induced instability, or over-sensitive response to transient influences, exacerbates the inherent supply variations.

Price Cycles:

Because of asset fixity and other related problems of resource immobility there is a likelihood of cyclical expansion and contraction of supply. Coupled with inelastic demand the result is cyclical price movements which cause farmers to enter and withdraw from production but which serve no economic function in the resource-allocating sense. Rather they result in a waste of resources as farmers continuously attempt to adapt to changing price signals. The most famous example of agricultural price cycles is with pigmeat, but blackcurrants afford another.

Figure (1)

Year-to-year Variations in Price



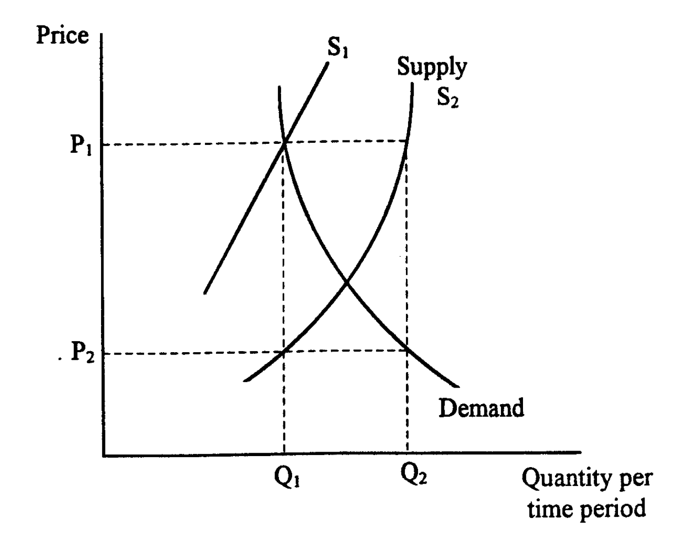
Where:

S_1 ≡ Supply in poor year
S_2 ≡ Supply in normal year
S_3 ≡ Supply in good year
P_1 ≡ Price in poor year
P_2 ≡ Price in normal year
P_3 ≡ Price in good year
Q_1 ≡ Quantity on poor year
Q_2 ≡ Quantity in normal year
Q_3 ≡ Quantity in good year

Figure (2)

The Progress of a Price Cycle

(an example of a Stable Cycle)



From the previous graph we can notice the dynamic nature of agricultural markets :

1- A temporary factor, such as poor weather, shifts supply curve to S_1 , and gives market price P_1 .
2- Interpreting this high price as permanent, farmers expand up their supply curves, and supply Q_2 .
3- Q_2 will only be taken off the market when price falls to P_2 .
4- Interpreting this low price as permanent. farmers contract supply to Q_1 . This again forces price up to P_1 .
5- Depending on the relative steepness of the S and D curves the cycle could be a contracting or expanding one. For simplicity we have assumed the case in which the cycle continues to alternate between the same highs and lows.

A price cycle is most likely to occur in an atomistic industry. such as agriculture, where there are large number of operators who each take decisions about production with no coordination with the decisions that others are taking simultaneously; where there is a lag between the decision to change the level of output and that output coming onto market to effect price; where demand is inelastic; where there is a problem of asset fixity; and where there are random disturbances to supply or demand to set off cycles. In farming all these conditions exist, though for some commodities more than others. The passage through a typical price cycle is illustrated in Figure (2) and explained in the notes relating to it.

2- Government Interference in the Market for Farm Products:

Bearing in mind the basic nature of the price system and the characteristics of the demand and supply experienced in agriculture, together with the price movements noted above, we next consider the ways in which the market system is manipulated by the state. Here we are concerned with market interventions which impinge more directly on farmers, such as subsidies they receive and quotas that constrain them. All we need note here is that mar-

ket intervention is used in various forms to achieve certain policy aims, such as raising the incomes of farmers through giving them higher prices for their products or lowering their costs of production, or increasing the level of self-sufficiency by raising the volume of production from home agriculture. Because of the complexity of the market intervention system, this chapter deals primarily with the principles of intervention mechanisms.

Buffer Stocks:

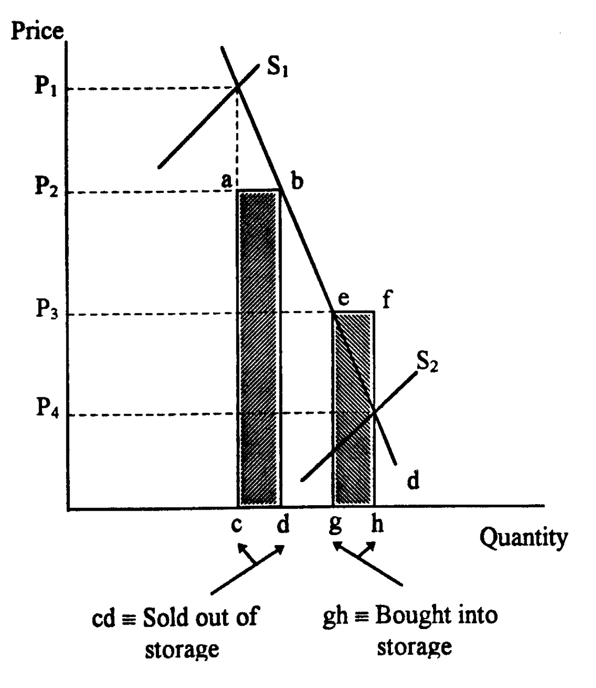
The simplest solution is the buffer stock principle, where intervention is designed to stabilize prices of those agricultural products that are subject to wide price variation brought about by weather influences on supply. The buffer consists of the state buying farm products when prices are low, taking them into storage, and releasing them onto the market when prices rise to unusually high levels. In reality no state agency will try to maintain a single, unfluctuating price. More likely it will set a minimum and a maximum price it is willing to see in the market, buying if the actual price tends to slide below the permitted range and selling if it appears to be likely to exceed the desired maximum. Figure (3) shows such an arrangement.

It is unlikely that the buffer stock managers will hit on exactly the right average price or range to maintain. What if they experience a run of low-yield, high-price years soon after setting up the buffer stock? The market deficit cannot be met (without buying in stocks from elsewhere) and the price rises above the desired maximum. What if there is a run of glut years ? Unwanted stocks build up. which must be destroyed, exported or otherwise got rid of. Attempts to give them away free to the poor and needy may be a socially and politically attractive solution, so long as the poor are a long way away ; otherwise the minimum desired price will be undermined.

The buffer may operate not simply to stabilize prices, but rather to stabilize revenues, that is price times quantity sold by producers. There may also be income implications of stabilization programme. These complications are beyond our treatment here. In practice, buffer stocks are not used in their pure form rather they become enmeshed with support buying, considered next.

Figure (3)

A Buffer Stock



Where:

- P_1 ≡ Free market price in poor year
- P_2 ≡ Highest permitted price
- P_3 ≡ Lowest permitted price
- P_4 ≡ Free market price in good year
- abcd ≡ Revenue from selling out of stock
- efgh ≡ Cost of buying into stock
- S_1 ≡ Supply in poor year
- S_2 ≡ Supply in good yea
- d ≡ Domestic demand

Support Buying:

The key to a buffer stock is the variation in supply that means a government (or its agent) is sometimes a buyer and sometimes a seller. In the case of support buying, the opportunity to be a seller seldom if ever exists. The government is providing farmers with a higher price than a free market would permit. To do this, it must operate on the internal and on the external markets. Figure (4) illustrates the situation when an internal price is fixed above the free market price. Farmers can sell as much as they like at this fixed price and the state buys up any excess. It is assumed that no imports or exports take place and that the government places a block on the entry of imports which might otherwise be attracted to the UK to take advantage of the raised prices.

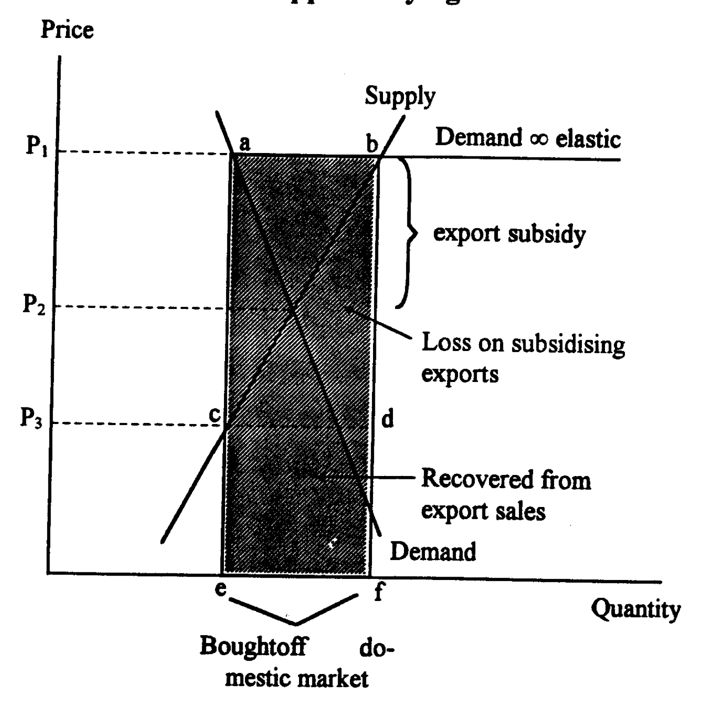
The without-intervention equilibrium situation would produce a price at which the quantity supplied to the market exactly balanced the amount demanded. If to support farm incomes, the government fixes price at a higher level, local farmers will produce an excess of supply over demand. This will accumulate in the state's stores. Clearly this accumulation cannot continue indefinitely and some way of disposal will need to be found. It could be destroyed by fire, changed in some way such as making wine

into industrial alcohol or butter into oil for which a market might exist, or simply left to rot, but this type of action is politically sensitive when there are members of the Community in need of an improved diet. Such action has also proved increasingly unacceptable when viewed against recurrent famines elsewhere in the world. To sell it cheaply to certain disadvantaged groups, such as the sales of butter stocks to old-age pensioners at Christmas, carries the danger of under-mining the normal market demand for butter as pensioners (sensibly) switch from full-price butter to the concessionary butter. One other method is to sell it to other countries, that is, put it on the world market. Let us assume that the world price is lower than both the supported price and that which would have brought demand into balance with domestic supply. Clearly, to sell off the excess supply abroad will need a subsidy to make it competitive. If in fact selling the excess supply on world markets actually reduces the world price, this subsidy will require to be even greater. The problem is worsened because the high price will encourage local farmers to invest and expand, shifting local supply rightwards, and enlarging the surplus.

This approximates to the operation of the EC system of intervention buying to achieve price support for its farmers. The open-ended commitment to buy production at

Figure (4)

Support Buying



Where:

P_1 = Buying-in price
P_2 = Free market price
P_3 = World price
ef = Bought off domestic market
bd = Export subsidy
abcd = Loss on subsidying export
cdef = Recovered from export sales

a fixed intervention price led to accumulating surpluses of major farm products (wheat, beef, butter and wine being some of the notable ones) and rising EC expenditure on storage and export subsidies, only recompensed in the rare event (as in 1974 for sugar) of the world price actually rising above the supported domes-tic level. Then the EC imposed a tax on exports which held the EC market price down.

Other problems are created by this system besides the budgetary cost. First, world market price are made lower and more variable as surplus domestic production, which will vary from year to year according to the weather and other short-term supply factors, is put on the world market at subsidized prices, a cause of complaint by traditional farm exporting economies in Austral:a and the Americas. Second, farmers lose the discipline of market forces and are unable to relate their costs to costs elsewhere or to the strength of consumer demand. Third, consumers pay higher prices than they need resulting.

Restricting Supply From Abroad:

Supported prices for domestic farmers can only be maintained if world market supplies at lower prices are kept off the home market. Where a significant proportion

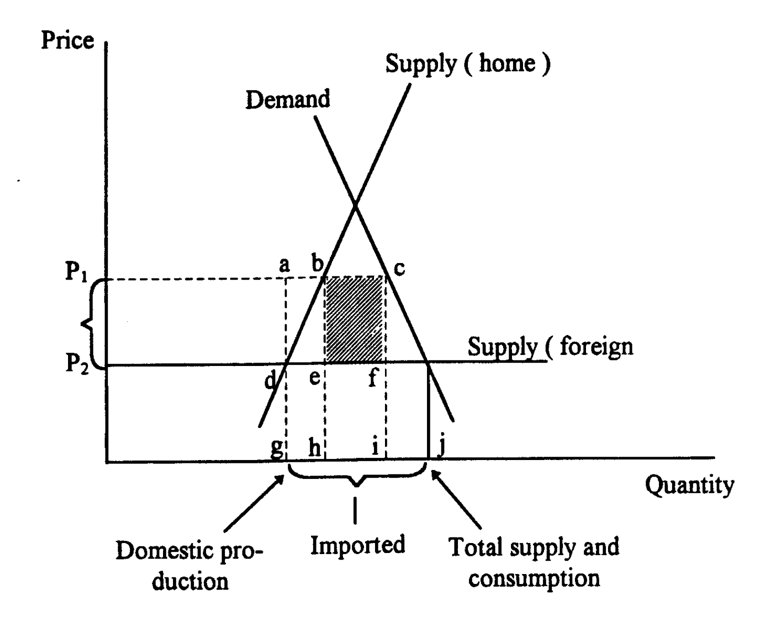
of total supplies normally come from abroad, it is possible to engineer price rises for domestic farmers by restricting this foreign supply without any domestic intervention buying or other government schemes.

To explain the workings of such methods of support it is necessary to go back to the idea of the world price, that is the price at which a country could import the commodity from foreign suppliers. For simplicity we will assume that this foreign supply is infinitely elastic, and the importing country could buy as much as it wished without affecting the world price. From Figure (5) it can be seen that in a free market situation some food would be imported at the world price and home farmers would produce some too.

Governments can attempt to establish higher home prices by minimum import prices. The EC uses these for fruit and vegetables (and the UK in the 1960 used them for cereals). Imports are only allowed into the country at this price, not below. This is an easy system to negotiate so long as supply is restricted to a few well-established countries because they can see a gain in prices they receive to offset their loss of sales in the country. The higher price for home farmers increases local supply and cuts local demand for the product and thus reduces the quantity of imports.

Figure (5)

A Levy on Imports



Where:

P_1 ≡ Domestic supported price
P_2 ≡ World price
bcef ≡ Revenue from import levy
g i ≡ Imported amount

Notes : 1- If prices are raised to home suppliers by using an import levy, home suppliers expand but imports are reduced by more, so that consumers take less from the market and pay higher prices for it.

2- If a levy is used there will be revenue to the state.

The minimum import price system has two major disadvantages. First, consumers paying higher prices for imports are needlessly helping to support foreign farmers as the importing country is consciously asking foreign countries to be more expensive. The second disadvantage is that the system creates monopolies and retards competition.

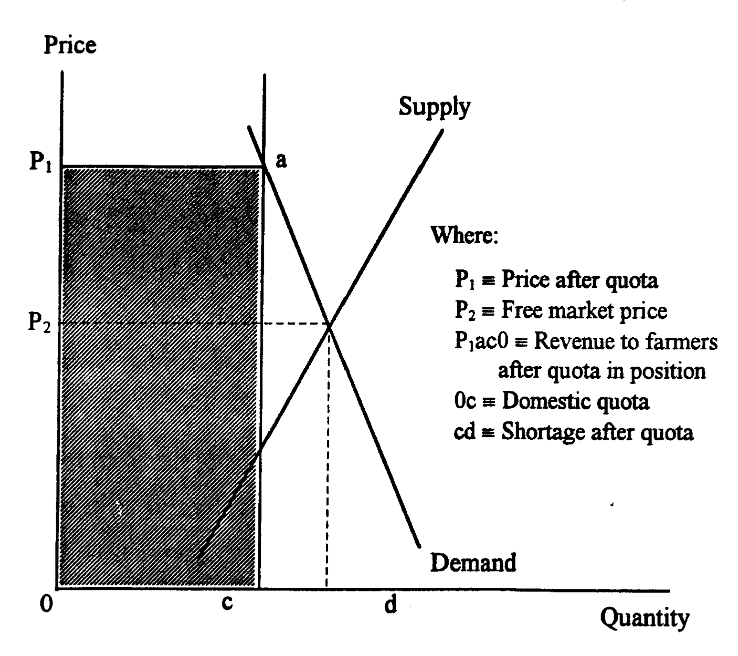
The obvious solution is to reject the minimum import price concept and buy from the cheapest source whilst maintaing a constant raised import price by imposing tax to bring up the import price to the desired domestic price. This is the variable import levy system used for most EC farm products. The EC monitors world prices or offer prices at its frontiers (the system varies from product to product) and imposes a levy on all imports based on the lowest import price to bring the price at which the imported produce sells within the EC up to the level which has been set as the target for domestic farmers. If a new supplier can sell for a lower price, the levy is increased for all importers. In this way, the two disadvantages, of the minimum import price are overcome. The higher prices paid by consumers on imported food are now balanced by revenue from the levies which is retained in the EC. Also suppliers must compete and offer competitive prices to be able to sell profitably within the EC.

quantity of output ; exceeding that output would result in a dilution of support as the available spending is spread over the greater volume of production. A similar notion is the **guarantee threshold**. Introduced in 1982, by 1985 there were guarantee thresholds for cereals, rape, sunflower and tomatoes. The threshold is usually the average EC production in the previous three marketing years. For cereals, the intervention price was reduced by 1 per cent for each 1.0 million tonnes of EC cereal production beyond the threshold level.

The advantage of such a system is that it is automatic. In an EC where political disagreement makes price-cutting difficult to achieve, measures are most likely to work when they are independent of the Council of Ministers and European Parliament, both open to strong pressure from the farming lobby. The problems with the guarantee thresholds are presently conceived are that they are far too timid in the amount of price penalty imposed for exceeding the threshold quantities, and they are still open to political manipulation. **Coresponsibility levies** are a further variant on this theme, with a tax being imposed on producers of commodities in surplus (really another form of price reduction) which is intended to assist with the disposal costs of excess production.

Figure (6)

Quota on Home Supply (no imports)



Notes : 1- By imposing a quota a new kinked supply curve is created.

2- Output is reduced, market prices rise.

3- Revenue to the farmer is raised (assuming demand is inelastic) - indicat-ed by the price x quantity rectangles.

Domestic Quotas:

Quotas are physical limits on the amount of output that farmers can produce. Potatoes in the UK have long

been the subject of acreage quotas, with the individual farmer restricted to the area he can grow. The Potato Marketing Board has thereby attempted to regulate the quantity of crop entering the market.

Physical Constrictions on Foreign Supply:

When imports form a significant portion of total supply, a physical limit on the volume of material that can be imported can raise prices for domestic farmers. Supply restriction from abroad can be done in several ways. The first is by some variant of voluntary restraint; foreign suppliers of apples for instance are simply asked not to send more than a certain tonnage of produce at times of the year when the domestic price would be sensitive to such supplies (i.e., July/August). The UK used this approach widely in the 1960s to limit imports (a bacon market-sharing arrangement with Denmark, a beef importing gentleman's agreement with Argentina and import quotas for sugar and butter). Currently it can be seen operating in the market for cars, in which Japan has agreed voluntarily to restrain its exports to the UK.

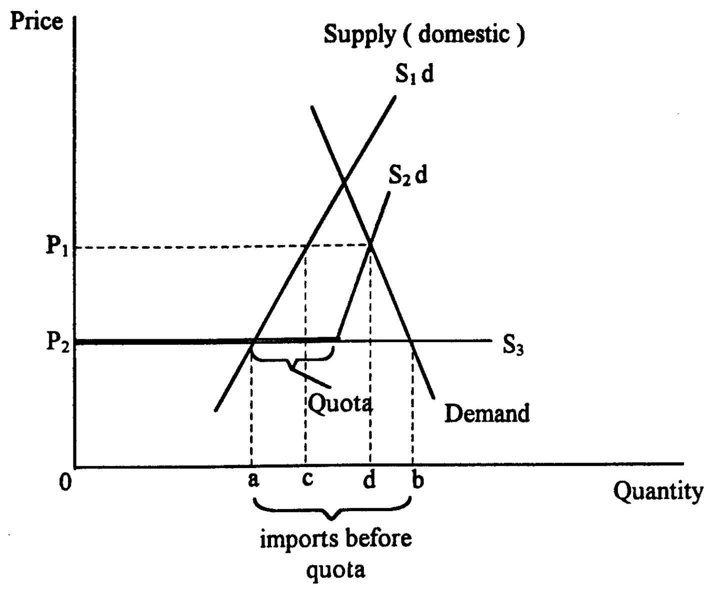
Other barriers to trade may be used which purport not to be formal ways of raising the prices enjoyed by home producers but have this effect. The zealous applica-

tion of health and hygiene controls may enable foreign food to be kept out (this has been used both by UK and France in the 1980s), the retention of cumbersome import documentation and show border customs, the insistence that imports travel in ships or lorries of the importing nation only and other trade impediments result in enhanced prices for home producers.

More formal limits on foreign supply could be imposed as quotas, illustrated in Figure (7) . Prices on the home market are increased as total supply contracts up the inelastic demand curve. Such a system has all the characteristics of any price raising measure, benefiting home producers through higher prices and easing the competitive pressure on them at the expense of consumers (particularly the poorer members of society and foreign suppliers), plus the problem of allocating the quotas and reallocating it as new producers arise.

Figure (7)

Quota on Imports



Where:

P_1 ≡ Home price after quota
S_1 d ≡ Domestic supply
S_3 ≡ World supply
cd ≡ Quota
db ≡ Shortage after quota

P_2 ≡ World price
S_2 d ≡ Domestic supply after quota
ab ≡ Imports berore quota
ac ≡ Expansion by home producers

Notes :

1- A quota on imports which is less than the initial level of imports gives the total supply curve a kink. The new supply curve intersects demand at a higher price.

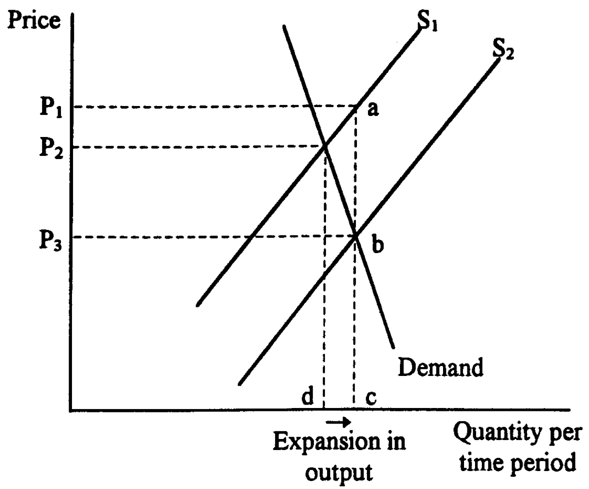
2- At the higher price domestic producers expand production. Foreign suppliers sell a reduced quantity but receive a higher price.

Production Bounties and Taxes:

Finally in this section we turn to production bounties, such as a payment for every calf sold from a farm or the closely related headage payment given to farmers keeping livestock in hill areas. The effect is to shift the supply curve for these enterprises downwards-farmers are willing to supply the same quantities to the market at a market price lower by the extent of the bounty than before. In terms of market price and output it is evident from Figure (8) that output rises and the market price falls somewhat, partly canceling out the benefit given to the farmer through the bounty, although this effect will depend on the elasticity of demand for the commodity in question. A tax on production would exert the opposite effect [Figure (9)]; not all the impact of the tax would fall on the farmer as the contraction in supply that would result would in part pass the burden to the consumer. One instance where such tax is used is on farmers who exceed quota levels of output; by penalizing over-quota production consumers have to pay more for their purchases.

Figure (8)

A Bounty (Subsidy) on Production



Where:

P_1 = Price received by farmers after policy
P_2 = Free market price $\quad$ P_3 = Market price after policy
S_1 = Supply before policy $\quad$ S_2 = Supply after policy
dc = Expansion in output due to policy $\quad$ ab = The amount of bounty

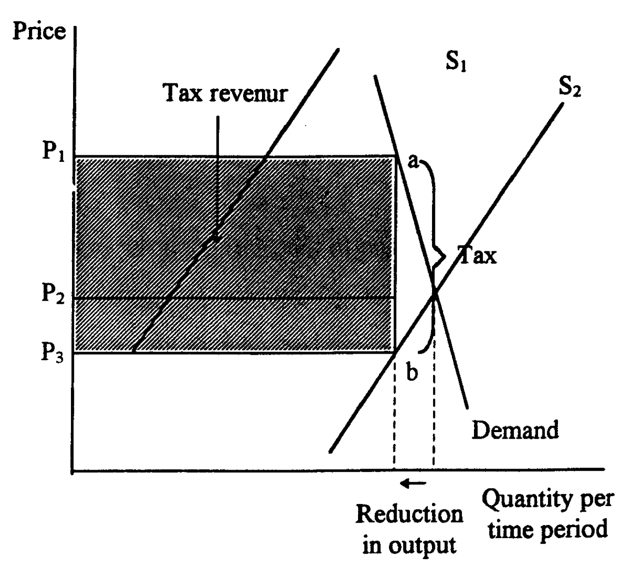
Notes : 1- A bounty (subsidy) lowers the supply curve by the extent of the bounty.

2- The producer expands in response to the bounty but this pushes down market price. Consequently, the final price the farmer receives is less than the original market price plus bounty ; it is the new lower market price plus bounty.

3- The benefit of the bounty is thus in part passed on to the consumer, the extent depending on the elasticity of demand.

Figure (9)

A Tax on Production



Where:

P_1 ≡ Price after tax P_2 ≡ Free market price
P_3 ≡ Price received by producer after tax
S_1 ≡ Supply before tax S_2 ≡ Supply after tax
$P_1 abP_3$ ≡ Tax revenue

Notes : 1- A tax on output raises the supply curve by the extent of the tax. Producers reduce output..

2- The market price is raised, but by less than the tax. The producer receives a lower price than before, but the fall is less than the size of the tax.

3- The division of the burden of the tax between consumer and producer will depend on the elasticity of demand.

We move from considering the intervention of the state in the markets for agricultural products to the ways in which it attempts to manipulate the markets for the inputs which farmers use.

3- Intervention in the Markets for Farming Inputs:

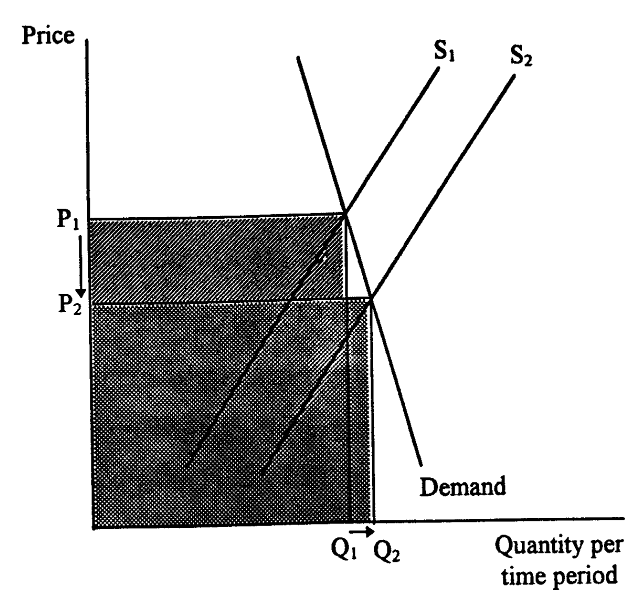
The state intervenes in the market for inputs by both direct methods and by influencing the supply and demand for them. It bans the use of certain insecticides and restricts the freedom of farmers to sell their land for building by the use of development planning control. In the mid-1980s there have been suggestions that problems of cereal and milk surpluses could be tackled by controls on the amounts of fertilizers that farmers may use. On the other hand, it compels farmers to buy safety equipment with their tractors and to maintain hygiene standards in milk production. But much of the influence on the input markets comes in the form of price manipulation.

The demand by farmers for inputs, both those used up in production within one cycle such as insecticides and those that are longer-lasting such as buildings, is derived from the demand for farm products. The supply of farm

products can be influenced by the cost of inputs. By taxing inputs and thereby raising their prices, government can reduce production; by subsidizing inputs, it can expand farm supply. Figures (10) and (11) illustrate the effect of a subsidy on an input (such as fertilizer); the effect is to shift the supply curve of the farm product which uses the subsidized input to the right as farmers are now willing to supply a greater volume of output at each market price than they were before. This will have an effect on the price of the product which depends on the market situation. In Figure (10) the rising supply meets inelastic demand and depresses price and revenue. In Figure (11), where there are imports and an infinitely elastic supply from the world market, the effect is to increase the amount supplied by home farmers whose rising output displaces imports. The subsidy will also be instrumental in helping the balance of payments (so long as the extra exports outweigh any extra imports of inputs).

Figure (10)

A Subsidy on Inputs (No Imports)



Where:

P_1 ≡ Price before subsidy P_2 ≡ Price after subsidy

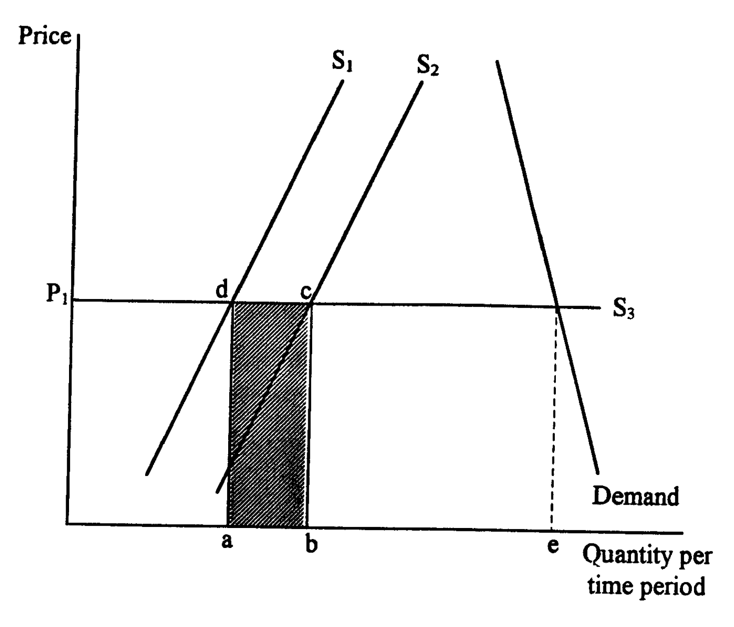
Q_1 ≡ Quantity before subsidy Q_2 ≡ Quantity after subsidy

Notes : 1- The effect on the market for the product of a subsidy on inputs is to move the supply curve to the right. Output rises.

2- The revenue to producers will fall if demand is inelastic (as shown here). whether producers are better or worse off will depend on the relative size of the revenue fall and subsidy.

Figure (11)

A Subsidy on Inputs (with Imports of Product)



Where:

P_1 ≡ World price
S_1 ≡ Home supply before subsidy
S_2 ≡ Home supply after subsidy
abcd ≡ Reduction in input bill

Notes : 1- The subsidy on input costs shifts the product supply curve to the right.

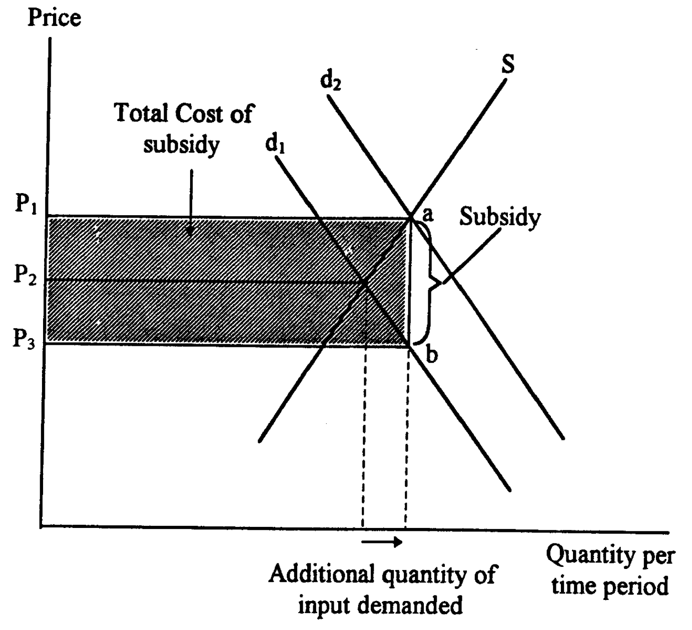
2- More home production occurs, displacing imports. Prices does not alter, as this is determined by the cost of imports. It is assumed that foreign supply is completely elastic.

4- Direct Payments to Farmers:

So far intervention in the market has been discussed in terms of altering the prices farmers receive for their produce or the costs they pay for their inputs. However, one way in which it is felt possible to influence the market for products is to make payments to farmers which can be enjoyed as income ; this may relieve them from the necessity to derive a livelihood from agricultural activity. The implication is that they will then not produce as much, thereby relieving in part the problem of over-production. It is known that a direct income payment without any conditions attached would affect neither the level of output nor the use of inputs; farmers would still behave as profit maximisers in the way they arranged their farms, although perhaps a modest reduction in activity might be exhibited by those who preferred to take more of their reward in the form of leisure.

Figure (12)

The Effect of an Input Subsidy on the Market for the Input



Where:

d_1 ≡ Demand before subsids

d_2 ≡ Demand with subsidy

S ≡ Supply

P_1 ≡ After subsidy market price

P_2 ≡ Free market price

P_3 ≡ After subsidy price

P_1 a b P_3 ≡ Total cost of subsidy

Notes:

1- A subsidy per unit raises the demand curve of the input by the extent of the subsidy.

2- The market price of the input rises.

3- The price paid by the farmer (after subsidy) falls, and he uses of the input.

4- Although part of the subsidy benefits farmer, some is passed on to the input supplier.

5- The more inelastic the supply of the input (the steeper the supply curve) the more the subsidy results in a price rise for the input supplied. In the extreme, when an input has totally inelastic supply (land) the subsidy simply results in an equivalent rise in market price. The farmer ends up paying the same net price.

On the other hand, direct payments could affect the markets for farm products and of inputs (especially land) if they were linked to specific actions by farmers. Under the EC policy towards disadvantaged areas, farmers on hill land are paid an income supplement linked to the number of livestock to encourage them not to follow the dictates of the market and abandon the land, but to remain; the objective is social and environmental rather than agricultural. While these payments could be regarded also as a production subsidy, it is clear that the objective is not concerned at all with encouraging output.

Agriculture Resources by Major Regions of the World

Region / Data items	Year	Africa	Europe	North America	Central America	South America	Asia	Units
Crop land								
Total	1994	190022000	316378000	233276000	41112000	114901000	611590000	hectares
Percapita		0.27	0.43	0.79	0.34	0.37	0.18	"
Cereal productes								
Total	1996	127583000	389960300	397073300	32304700	94049200	973121600	metrictons
Percapita	1996	0.17	0.44	1.33	0.26	0.29	0.28	"
Pasture land	1994	883812000	179132000	267072000	98472000	494777000	1046888000	hectares
Annual fertilizer use	1994	18	157	92	58	60	129	Kg/hectare
Average cereal yield	1994-96	1220	2884	36795	-	2547	2895	" "
Net trade in cereal average	1993-95	31242000	-20823000	-108419	12216	4361	77933000	metric tons

From : World Resources 1998-1999



Chapter 11

Economics of Population

In this chapter, we examine many of the issues relating population growth to economic development. We begin, however, by looking at historical and recent population trends and the changing geographic distribution of the world's people. After explaining basic geographic concepts, we present some well-known economic models hypotheses regarding the causes and consequences of rapid population growth in developing countries. Finally, we evaluate a range of alternative policy options that developing countries may wish to adopt to influence the size and growth of their population.

1- The Basic Issue: Population Growth and The Quality of Life:

Every year, more than 93 million people are being added to the world's population of 6 million. More than 82 million (88%) of these additional people per year will be born in developing countries. The problem of population growth is not simply a problem of number, it is a problem of human welfare and economic development.

Rapid population growth can have serious consequences for many developing countries.

The basic question here is how does development affect population growth?

Among the major issues relating to this question are the following:

1- Will developing countries be capable of improving the levels of living for their people with the current and anticipated levels of population growth ? To what extent does rapid population increase the difficulty to provide essential social services, housing, transport, and security?

2- How will the developing countries be able to absorb the vast increases in their labor forces over the coming decades?

3- What are the implications of higher population growth rates among the poor developing countries?

4- Given the anticipated population growth, will developing countries be able to extend the coverage and improve the quality of their health and educational systems so that everyone can at least have the chance to secure adequate health care and a basic education?

5- To what extent are low levels of living are important factors in limiting the freedom of parents to choose a desired family size ? Is there a relationship between poverty and family size?

A Review of Numbers:

Population Growth: Past, Present, and Future:

- World Population Growth Through History:

Throughout most of the more than 2 million years of human existence on earth, humanity's numbers have been few. When people first started to cultivate food through agriculture some 12000 years ago, the estimated world population was no more than 5 million, less than number of people living today in Mexico city or Cairo city. At the beginning of the Christian era, nearly 2000 years ago, world population had grown to nearly 250 million, less than a quarter of the population in China today.

By the year 2000, the world's population will be almost 6.3 billion, see the next table :

2- *The Causes of High Fertility in Developing Countries:*

(A) The Malthusian Model:

Almost 200 years ago, Thomas Malthus put forward a theory of the relationship between population growth and economic development that still survives today.

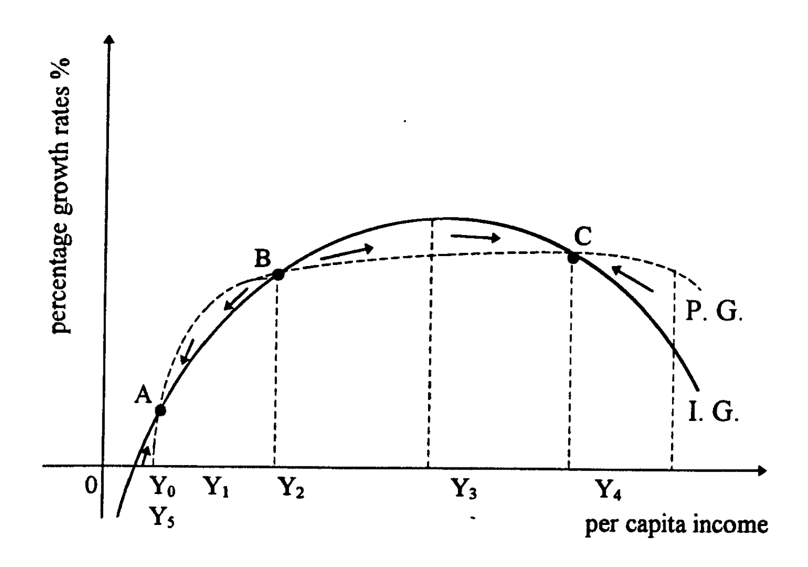
Malthus stated that the food supplies grow at an arithmetic rate ; 1, 2, 3, 4, 5. While population increases at a roughly geometric rate ; 1, 2, 4, 8, 16. Because the growth in food supplies could not satisfy the needs of increased population, per capita incomes would have to fall.

The basic Malthusian model can be illustrated by comparing the shape and position of curves representing population growth rates and aggregate income growth rates when these two curves are each plotted against levels of per capita income. This is done in the following figure :

On the vertical axis we plot numeric percentage changes, both positive and negative. On the horizontal axis are levels of per capita income.

Figure (1)

The Malthusian population Trap



1- The Relationship Between Population Growth (P.G.) and Per Capita Income:

At a very low level of per capita income, Y_0, the rate of population change will be zero, and a stable population will exist (birth rates = death rates). At per capita income levels to the right of Y_0, it is assumed that population size will begin to increase under the pressure of falling death rates (birth rates > death rates).

Population growth achieves its maximum rate at a per capita income level of Y_2 . It is assumed to remain at that level until much higher per capita income levels are realized thereafter (beyond Y_5), birth rates will begin to decline, and the population growth rate curve (P.G.) becomes negatively sloped.

2- *The Relationship Between Income Growth (I.G.) and Per Capita Income:*

In Figure (1) , the rate of aggregate income growth is assumed at first to be positively related to levels of per capita income, that is, the higher the level of per capita income, the higher the rate of increase in aggregate income.

The economic reason for this positive relationship is the assumption that savings vary positively with per capita income. Countries with higher per capita incomes are assumed to be capable of generating higher saving rates and thus more investment.

Beyond a certain per capita income point (Y_3) , the income growth rate curve is assumed to level off and then begins to decline as new investments and more people are required to work with fixed quantities of land and natural resources. This is the point of diminishing returns in the Malthusian model.

In Figure (1), the two curves intersect at three points, A, B, C. Point (A), represents the point at which the Malthusian population trap level of per capita income (Y_1) is attained. It is a stable equilibrium point, any small movement to the left or to the right of point (A) will cause the per capita income equilibrium point to return to Y_1. For example, as per capita income rises from Y_1 to Y_2, the rate of population increase will exceed the rate of aggregate income growth (the P.G. curve is vertically higher than the I.G. curve) . For all points between Y_1 & Y_2, per capita income must fall back to its low level at Y_1.

Similarly, to the left of point (A), income grows faster than population, causing the equilibrium per capita income level to rise to Y_1 .

Completing our description of the population trap, we see that point (B) is an " unstable " equilibrium point. If per capita income can somehow jump rapidly from Y_1 to Y_2 (as a result of " big push " investment), it will continue to grow until the other stable equilibrium point (C) at per capita income level (Y_4) is reached. Point (B) is an unstable equilibrium point in the sense that any movement to the left or to the right until either (A) or (C) is reached.

Criticisms to The Malthusian Model:

The Malthusian population trap provides a single theory of the relationship between population growth and economic development. Unfortunately, it is based on a number of simplistic assumptions and hypotheses that do not stand the test of empirical verification.

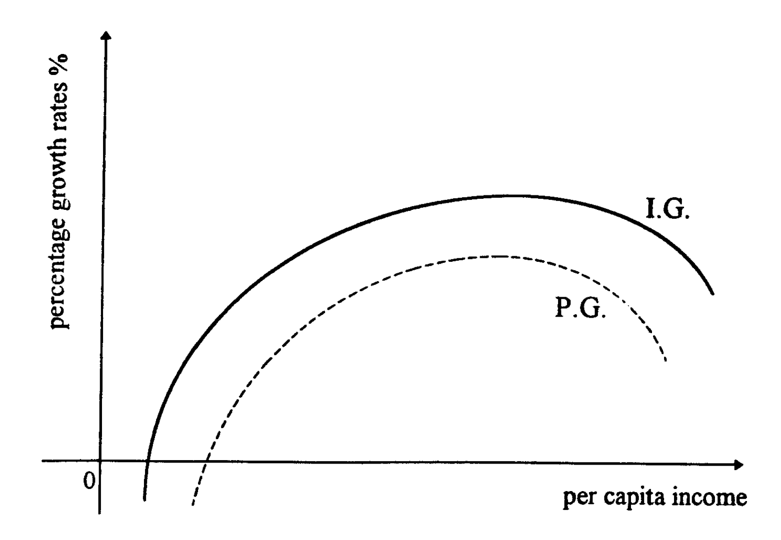
We can criticize the population trap on two major grounds:

First, and most important, the model assumes away or ignores the enormous impact of technological progress in offering the forces of rapid population increases. While Malthus was basically correct in assuming a limited supply of land, he did not anticipate the manner in which technological progress could augment the availability of land by raising its quality and its productivity.

In terms of population trap, rapid and continuing technological progress can be represented by an upward shift of the income growth (total product) curve, so that at all levels of per capita income it is vertically higher than the population growth curve. This is shown in the next Figure (Figure 2).

Figure (2)

How technological progress allow countries to avoid the population trap



In Figure (2), per capita income will grow steadily over time. All countries have the potential of escaping the Malthusian population trap.

The second basic criticism of the trap focuses on its assumption that national rates of population increase are directly (positively) related to the level of national per capita income. According to this assumption, at relatively low levels of per capita income, we should expect to find

population growth rates increasing with the increase of per capita income.

But researches on developing countries indicates that there appears to be no clear correlation between population growth rates and levels of per capita income among developing countries.

As a result of modern and health programs, death rates have fallen rapidly and have become less dependent on the level of per capita income.

We can thus largely reject the Malthusian theory on the following grounds:

1- It does not take adequate account of the role and impact of the technological progress.
2- It is based on hypotheses about a macro relationship between population growth and levels of per capita income that does not stand up to empirical testing.
3- It focuses on the wrong variable, per capita income, as the principal determinant of population growth rates.

(B) The Household Model:

(Microeconomic Household Theory of Fertility)

In recent years, economists have began to look more closely at the microeconomic determinants of family fer-

tility in an attempt to provide a better theoretical and empirical explanation for observed birth rates. In doing this, economists, have used the theory of consumer behavior and the principles of optimization to explain family size decisions.

The theory of consumer behavior assumes that an individual with a given set of tastes or preferences for a range of goods tries to maximize the satisfaction derived from consuming these goods subject to his own income constraint and the relative prices of all goods.

In the application of this theory to fertility analysis, children are considered as a special kind of consumption good so that fertility becomes a rational economic response to the consumer's demand for children relative to other goods. That is, if other factors are hold constant, the desired number of children can be expected to vary directly with household income, inversely with the price (cost) of children, and inversely with the strength of tastes of other goods relative to children.

Mathematically, these relationships can be expressed as follows :

$$C_d = f(Y, P_c, P_x, t_x) \; ; \; x = 1, \ldots\ldots, n$$

Where :

C_d : The demand for surviving children.
Y : The given level of household income.
P_c : The net price of children (the difference between anticipated costs, and benefits) .
P_x : The prices of all goods, and
t_x : The tastes for goods relative to children.

Under normal conditions, we would expect that :

- $\frac{\partial C_d}{\partial Y} > 0$; the higher the household income, the greater the demand for children.
- $\frac{\partial C_d}{\partial P_c} < 0$; the higher the net price of children, the lower the quantity of children demanded.
- $\frac{\partial C_d}{\partial P_s} > 0$; the higher the prices of all other goods relative to children, the greater the quantity of children demanded.
- $\frac{\partial C_d}{\partial t_x} < 0$; the greater the strength of tastes for goods relative to children, the fewer children demanded.

The following Figure (3) provides a simplified diagrammatic presentation of the microeconomic theory of

fertility. The number of desired (surviving) children, C_d , is measured along the horizontal axis, and the total quantity of goods consumed by the parents, G_p , is measured on the vertical axis.

Household desires for children are expressed in terms of an indifference map representing the subjective degree of satisfaction desired by the parents for all possible combinations of commodities and children. Each individual indifference curve portrays a locus of commodity children combinations that yield the same amount of satisfaction. Any point (or combination of goods and children) on a "higher" indifference curve represents a higher level of satisfaction than any point on a lower indifference curve. But each indifference curve is a "constant satisfaction" locus.

In Figure (3), only four indifference curves, I_1 to I_4, are shown. The household's ability to "purchase" alternative combinations of goods and children is shown by the budget constraint line, ab. Thus all combinations on or below line ab are financially attainable by the household on the basic of its income and the relative prices of children and goods, as represented by the slope of the ab budget constraint line. The steeper the slope of the budget line, the higher the price of children relative to goods.

According to the demand - based theory of fertility, the household chooses from among all attainable combinations the one combination of goods and children that maximizes family satisfaction.

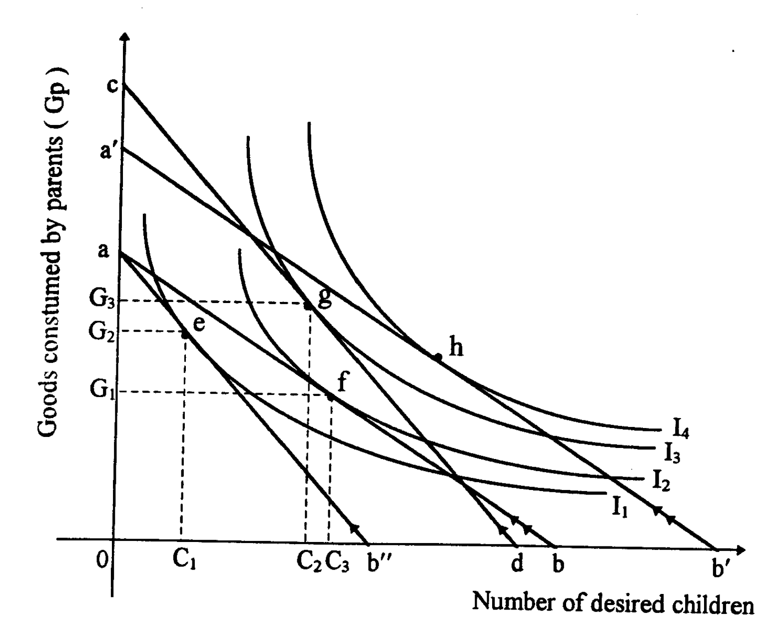
Diagrammatically, this optimal combination is represented by point (f), the tangency point between the budget constraint line, ab, and indifference curve (I_2). Therefore, C_3 children and G_2 goods will be demanded.

A rise in family income, represented in Figure (3) by the parallel outward shift of the budget line from ab to a′b′, enables the household to attain a higher level of satisfaction (point h on curve I_4) by consuming more of both commodities and children.

Similarly, an increase in the price (opportunity cost) of children relative to other goods will cause household to substitute commodities for children. Other factors (namely, income and tastes) being constant, a rise in the relative price of children causes the household utility maximizing consumption combination to occur on a lower indifference curve, as shown by the movement of the equilibrium point from (f) to (e) when the budget line rotates around point (a) to ab″.

Figure (3)

Microeconomic Theory of fertility : An Illustration



Note, finally, that if there is a simultaneous increase in household income and net child price as a result of, say, expanding female employment opportunities and a rise in wages coupled with a tax on children beyond a certain number per family, there will be both an outward shift and downward rotation of the budget constraint line of Figure (3), say, dashed line cd The result is a new utility-maximizing combination that includes fewer children per

family (point g compared with point f). In other words, higher levels of living for low - income families in combination with a relative increase in the price of children will motivate household to have fewer children while still improving their welfare. This is just one example of how the economic theory of fertility can shed light on the relationship between economic development and population growth as well as suggest possible lines of policy.

3- The Demand for Children in Developing Countries:

As we have seen, the economic theory of fertility assumes that the household demand for children is determined by family preferences for a certain number of surviving children. Children in poor countries are seen partly as economic investment goods in that there is an expected return in the form of both child labor and the provision of financial support for parents in old age.

However, in many developing countries there is a strong psychological and cultural determinant of family size, so that the first two or three children should be viewed as "consumer" goods for which demand may not be very responsive to relative price changes.

The choice mechanism in the economic theory of fertility as applied to developing countries is assumed, therefore, to exist primarily with regard to the additional or marginal children who are considered as investments. In deciding whether or not to have additional children, parents are assumed to weigh economic benefits against costs, where the principal benefits, as we have seen, the expected income from child labor, usually in the farm, and financial support for elderly parents. Balanced against these benefits are the two principal elements of cost :

1- The opportunity cost of the mother's time.

2- The opportunity and actual cost of educating children.

Statistical studies in many developing countries support the economic theory of fertility. These studies found that high female employment opportunities outside the home and greater female and male school attendance are associated with lower levels of fertility. Moreover, these studies have confirmed the strong association between declines in child mortality and the subsequent decline in fertility.

Finally, although increased income may enable the family to support more children, the evidence seems to

show that with higher incomes, parents will tend to substitute child quality for quantity by investing in fewer, better-educated children. It is further argued that more income may also tend to lower fertility because the status effect of increased income raises the relative desire for material goods, especially among low - income groups.

In short, birthrates among the very poor countries are likely to fall where there is :

1- An increase in the education of women.
2- An increase in female nonagricultural wage employment opportunities.
3- A rise in family income levels through the increased direct employment and earnings of a husband and wife.
4- A reduction in infant mortality through expanded public health programs.

Chapter 12

Economics of Health

Grossman used the theory of human capital to explain the demand for health and health care. His work has become a standard beginning point for much subsequent work. According to human capital theory, individuals invest in themselves through education, training, and health to increase their earnings. Grossman show the way in which many important aspects of health demand differ from the traditional approach to demand :

1- It is not medical care per se that the consumer wants, but rather health. Medicalcare demand is a derived demand for an input to produce health. People want health ; they demand inputs to produce it.

2- The consumer does not merely purchase health passively from the market. Instead, the consumer ***produces*** it, spending time on health-improving efforts in addition to purchasing medical inputs.

3- Health lasts for more than one period. It does not depreciate instantly, and thus can be treated like the capital good that it is.

4- Perhaps most importantly, health can be treated both as a consumption good and an investment good. As a consumption good, health is desired because it makes people feel better. As an investment good, health also is desired because it increases the number of healthy days available to work, and thus to earn income.

Consider the consumer, Ed Kramer as a producer, or a firm that buys market inputs (e.g., medical care, food, clothing), and combines them with his own time to produce the services that increase his utility. The consumer not only increments his stock of health but using market inputs and personal time produces the other pleasures of life.

These pleasures are meant to include virtually all other things that the consumer does. Included are time watching television, reading, playing with and teaching one's children, preparing meals, baking bread, or watching the sun set. We do not mean that they are all simply pleasures. Instead, they are intended to represent a composite of other things we do with our leisure time, both for pleasure and out of a sense of duty to family and community. We shall call this composite ***home good B***.

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Time Spent Producing Health:

An increment to capital stock such as health is called an investment. Each period Ed produces an investment in health, I. Health investment, I, is produced by time spent improving health, T_H, and market health inputs (providers' services, drugs, exercise), M. Likewise, home good B is produced with time, T_B, and market-purchased goods, X[1]. Thus, Ed is using money to buy health care inputs, M, or home good inputs, X. He is using leisure time either for health care (T_H) or for producing the home good (T_B).

Using functional notation :

$$I = I(M, T_H; E) \qquad (1)$$

$$B = B(X, T_B; E) \qquad (2)$$

These functions indicate that increased amounts of M and T_H increase I, and that increased amounts of X and T_B increase B. The variable E in these functions is included to suggest that productivity in producing I or B may vary from person to person. Grossman proposed that this technical efficiency level would be related to the individual's education level, E. That is, educated people may produce one good or the other more efficiently.

In this model, Ed Kramer's ultimate resource is his own time. Treat each period of analysis as being a year in length, and assume that Ed has 365 days available in the year. To buy market goods such as medical care, M, or other goods, X, he must trade some of this time for income; that is, he must work at a job. Call his time devoted to work T_W. Because our focus is on the health aspects of living, we realize that some of his time during each year will be taken over by ill health, or TL. Thus, we have accounted for his total time in the following manner :

Total time = T = 365 days = T_H (time spent improving health)

+ T_B (time spent in producing home goods)

+ T_L (time lost due to illness)

+ T_W (time devoted to work)

Recall that his leisure time is spent either improving his health or producing home goods.

Labor-Leisure Trade-Off:

The potential uses of Ed's time are illustrated by the labor-leisure trade-off. Our variation on this analysis also helps illustrate the investment aspects to health demand.

Trading Leisure for Wages:

In Figure (1), the X-axis represents Ed's work and leisure time. Suppose that he considers his time spent creating investment to be "he-improvement time" and that he calls T_B his leisure. In reality, he may do some health-improving activities at work. may obtain some enjoyment or satisfaction from healthful time, and so on, but assume here that these categories are exclusive. Assume further that the number of days lost to ill health and the number of days spent on health-enhancing activity are fixed (we relax this assumption later). Variables T_{L0} and T_{H0} refer to time lost and time spent on healthy activities, respectively. The maximum amount of time that he has available to use for either work, T_W, or leisure, T_B, is thus $365 - T_{H0} - T_{L0}$, so :

$$\text{Time Available for Work or Leisure} = 365 - T_{H0} - T_{L0}$$

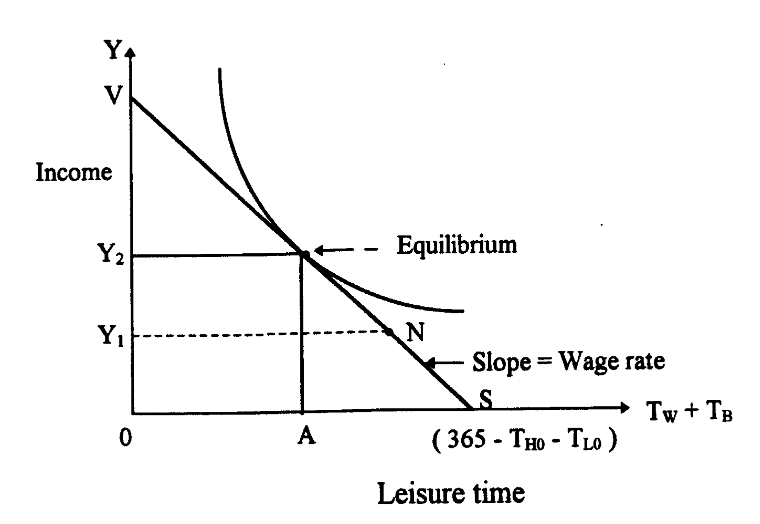
$$= T_W + T_B$$

Thus, leisure time, T_B, is measured toward the right while time spent at work, T_W, is measured toward the left. For example, if Ed chooses leisure time, 0A, then he has simultaneously chosen the amount of time at work indicated by AS. These are indicated in Figure (1).

Recall that Ed's total amount of time available for either work or leisure is given by point S. If he were to choose point S for the period, he would be choosing to spend all this available time in leisure; that is, in the pursuit of the pleasures of life (albeit without the wage income to produce them). The y-axis represents income, which can be obtained through work. This income can be used to purchase either market health goods or other market goods. Thus, if he chooses point S, he will be able to purchase no market goods because he has no earned income.

Figure (1)

Labor-Leisure Trade-off



If beginning at S, Ed gives up one day of leisure by spending that day at work, to point. N, he will generate income equal to $0Y_1$. $0Y_1$ thus represents his daily wage. In economic terms, this quantity represents income divided by days worked that is, the daily wage. Thus, the slope of the line VS depicting the labor-leisure trade-off reflects the wage rate.

Preferences Between Leisure and Income:

As before, Ed would like more and more leisure, so the indifference curve map is shaped normally. In equilibrium, Ed's trade-off of leisure and income is the same as the market trade-off, which is the wage rate. Here, he takes amount 0A of leisure and trades amount AS of leisure for income, $0Y_2$.

Ed has made a different choice with respect to time spent investing in health status. To illustrate, suppose that time spent on health-producing activities, T_H, is increased from T_{H0} to T_{H1}. Correspondingly, suppose that the number of days lost to ill health has been reduced from T_{L0} to T_{L1}. What effect will this have on the horizontal intercept, which is the total time remaining for work or leisure ? On the one hand, time spent producing health reduces time available for other activities. On the other hand, time spent

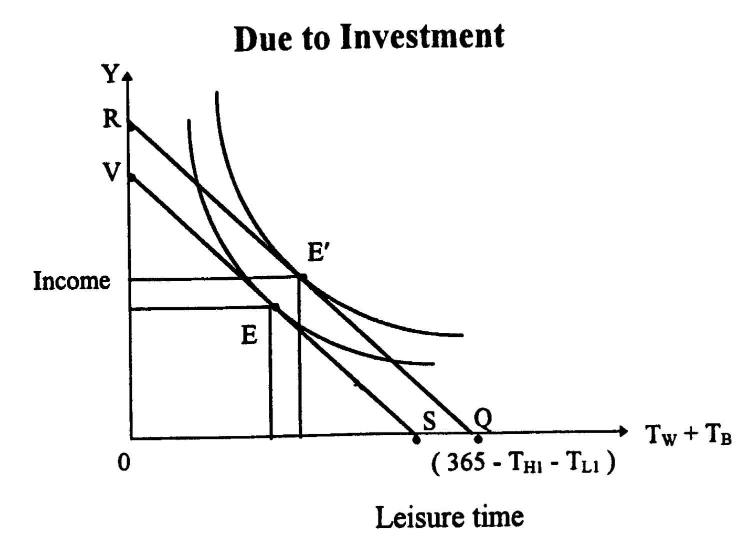
on health investment increases health stock and in turn reduces time lost to illness.

If the net effect is a gain in available time, then this illustrates the pure investment aspect of health demand. The health investments "pay off" in terms that not only add to potential leisure but that also increase the potential income, shifting the income-leisure curve outward from VS to RQ. The expenditure of time (and medical care, too) for health-producing activities may later improve Ed's available hours (because he is sick less) of productive activity.

Figure (2)

Increased Amount of Healthy Time

Due to Investment



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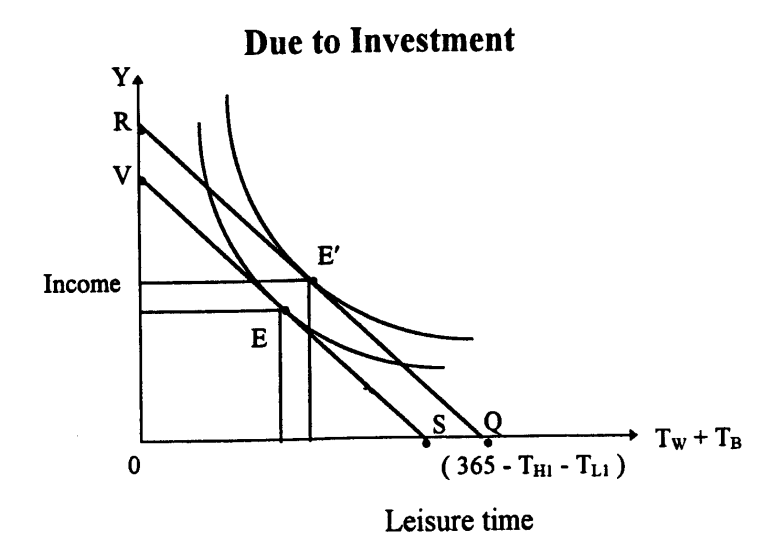
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Increased Amount of Healthy Time

Due to Investment



As a result of his investment, Ed can increase his utility, moving from point E to point E′. Not only does investment in health lead to his feeling better, but it also leads to more future income and may lead to more leisure, as well.

The improvement in health status also might increase Ed's productivity at work, perhaps resulting in a higher wage and thus a steeper income-leisure curve. In any case, it is clear that Ed might wish to engage in activities to improve his health, even if the only value of health is its effect on his ability to earn future income.

The Investment/Consumption Aspects of health:

The Grossman model describes how the consumer simultaneously makes choice over many periods or years. It is also instructive, on occasion, to represent a whole life span as a single period. This can show the dual nature of health as both an investment good and a consumption good.

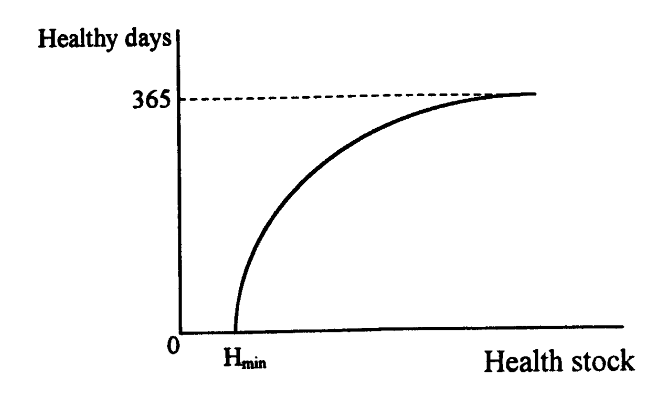
Production of Health Days:

Health is productive good that produces healthy days. This production function relationship is illustrated. The horizontal axis measures health stock in a given pe-

riod. The greater one's stock of health, the greater the number of healthy days up to a natural maximum of 365 days. The bowed shape of the curve illustrates the law of diminishing marginal returns (additional resources have decreasing marginal impacts on the output). Note also the concept of a health stock minimum shown as M_{min}. At this point, production of healthy days drops to zero, indicating death.

Figure (3)

Relationship of Healthy Days to Health Stock



Production of Health and Home Goods:

Consider the possibilities for producing health, H, and home good, B, given the total amount of time available. Figure (4) shows this production possibilities trade-off. Note that the curve differs from the usual production

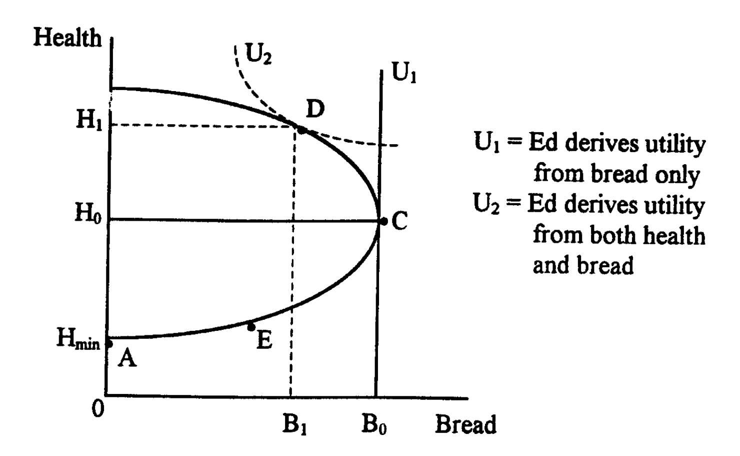
possibilities curve in several respects. First, from point A to point C, increments to health increase the amounts of both home good, B, and health, H, attainable. It is necessary to increase health beyond H_{min} in order to obtain income and leisure time from which to produce B.

Moving along the production possibilities curve, Ed Kramer is shifting his of available time and is distributing his purchases of market goods. Thus, the move from E to C indicates that he has made more time available for health and that this move has reaped the side benefit (increased leisure time) of increasing the availability of market goods and time used to increase production of bread.

Suppose that Ed gets no psychic benefit at all from health; that is, health is desired solely for its effect on the ability to produce income and the leisure time to produce the home good bread, B. This would imply that his indifference curves between H and B would be vertical lines. (Ed places no intrinsic value on H, so he would not trade any B to get additional healt). In such a case, he would maximize his utility by producing as much B as possible. The utility-maximizing choice would be at point C, a point of tangency between indifference curve U_1 and the production possibilities curve. He produces amount B_0 of the home good, and H_0 of health.

Figure (4)

Allocation of Resources Between Health and Bread



Now assume instead that Ed achieves utility not only from producing B, but also directly from health itself (he likes feeling better). In this case, his indifference curves U_2, have the more familiar shape in Figure (4), sloping downward from left to right. It is more realistic to say that he values health both as a consumption good, as is shown in Figure (4), and as an investment in productive capacity, The former suggests that enjoys feeling healthy; the latter, that feeling healthy makes him more productive, thus allowing him to earn more, In general, by including Ed's "feeling healthy" in this consumption feature of the model,

he will choose a higher health stock than under the pure investment model. Health stock, H_1, exceeds H_0 in Figure (4). This is achieved by Ed's taking less home good, or $B_1 < B_0$.

Investment Over Time:

Choices are made for the many periods over one's life cycle, rather than just for one representative period. As a beginning point for each analysis, we feature the pure investment version of the model (point C in Figure 4). We then discuss the analytical changes when consumers, in addition, value health intrinsically (point D in Figure 4).

Because health is a capital good, it is necessary to understand the cost of capital as well as the capital good demand process. A health clinic, for example, purchases ththousands of dollars of X-ray equipment. The return to the X-ray equipment is in the future earnings that ownership of the equipment can provide.

Suppose that an X-ray machine costs $ 100.000, and that its price does not change over time. Suppose that the annual income attributable to the use of the X-ray machine is $ 20.000. Is purchasing the machine a good investment? Consider the alternative: In stead of purchasing the X-ray

machine, the clinic could have put the $ 100.000 in a savings account, at 5 percent interest, yielding the following;

$100.000 \times 1.05 = 105.000$ at the end of Year 1

$105.000 \times 1.05 = 110.250$ at the end of Year 2

$110.250 \times 1.05 = 115.763$ at the end of Year 3

$115.763 \times 1.05 = 121.551$ at the end of Year 4

$121.551 \times 1.05 = 127.628$ at the end of Year 5

For the investment in an X-ray machine to be desirable by these criteria, it should provide at least $ 27.628 in incremental revenue over the five years.

The problem is more complicated, however, because most capital goods depreciate over time. Suppose that the clinic knows that the X-ray machine will wear out (or depreciate), so that it will be worth only half its original value in five years. The clinic must earn enough not only to cover the opportunity cost from the bank, but also to maintain the value of the machine. For the investment to be worthwhile, then, it must not only earn the competitive 5 percent return each year, it also must provide enough return to cover depreciation of the machine. This suggests that the cost of holding this capital good for any one year, as well as over

time, will equal the opportunity cost of the capital (interest foregone) plus the depreciation (deterioration of value).

The Demand for Health Capital:

Conventional economic analysis provides a powerful conceptual apparatus by which to analyze the demand for a capital good. The cost of capital, in terms of foregone resources (for health capital, both time and money), is a supply concept, The other needed tool is the concept of the marginal efficiency of investment, the MEI, a demand concept that relates the return investment to the amount of resources invested.

Marginal Efficiency of Investment (MEI) and Rate of Return:

The MEI can be described in terms of the X-ray machine example. A busy clinic may wish to own more than one X-ray machine. But how many ? The clinic management may logically consider them in sequence. The first machine purchased (if they were to buy only one) would yield a return as we have discussed. Suppose that return each year were $ 20.000.

We also can calculate the rate of return, which would be $ 20.000/$ 100.000 or 20 percent per year. The

management would buy this machine of the incremental revenue brought in covered its opportunity cost of capital and the depreciation. In terms of rates, management would choose to own the first X-ray machine as long as the rate of return, 20 percent, were greater than the interest rate (the opportunity cost of capital) plus the depreciation rate.

If management considered owning two machines, it would discover that the rate of return on the second X-ray machine probably would be less than the first. To understand this, consider that a clinic buying only one X-ray machine would assign it to the highest-priority uses, those with the highest rate of return. If the clinic were to add a second X-ray machine, then logically it could be assigned only to lesser-priority uses (and might be idle on occasion). Thus, the second machine would have a lower rate of return than the first. The clinic would then purchase the second machine only if its rate of return were still higher than interest plus depreciation.

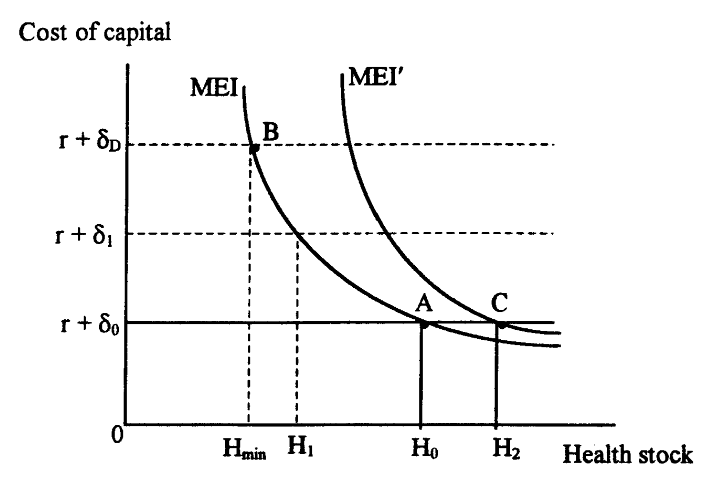
The Decreasing MEI:

Other machines probably could be added at successively lower rates of return. In Figure (5), the marginal efficiency of investment curve, MEI, describes the pattern of rates of return, declining as the amount of investment

(measured on the horizontal axis) increases. In Figure (5), the cost of capital (that is, the interest rate, r, plus the depreciation rate, δ_0) is shown as the horizontal line labeled $(r + \delta_0)$. The optimum amount of capital demanded is thus H_0, which represents the amount of capital at which the marginal efficiency of investment just equals the cost of capital. This equilibrium occurs at point A.

Figure (5)

Optimal Health Stock



Like the marginal efficiency of investment curve in this example, the MEI curve for investments in health also would be downward sloping. This occurs because the pro-

duction function for healthy days (see Figure 6) exhibits diminishing marginal returns. The cost of capital for health would similarly reflect the interest rate plus the rate of depredation in health. Understand that a person's health, like any capital good, also will depreciate over time. Thus, the optimal demand for health is likewise given at the intersection of the MEI curve and the cost of capital curve ($r + \delta_0$).

Changes in Equilibrium: Age, Wage, Education and Uncertainty

The depicted in Figure (5) provides a useful way to investigate several important model implications. Return to Ed Kramer. How does his investment in health change in response to changes in age, wage, and education ? Consider age first.

Age:

One may ask in this context how the consumer's optimal stock of health varies over a lifetime. In this model, the person's death itself is endogenous. Endogenous means that this variable is determined within the model, not external to it. Ed chooses his optimal life span, a life span that is not infinite. By this model, all of us, at some time, will optimally allow our health stock to dissi-

pate to H_{min}. This feature depends in critical way on how the depreciation rate varies with age.

The rate at which Ed's health stock depreciates may increase during some periods of life and decline during others. Eventually, as he ages, the depreciation rate is likely to increase. In other words, the health of older people is likely to deteriorate faster than the health of younger people.

Consider then the effect of aging on Ed's optimal health stock. Return to Figure (5) . We assume that the wage and other features determining the MEI are not substantially altered by this aging. However, by hypothesis, the depreciation rate, δ. increases with age from δ_0 to δ_1 and ultimately to δ_D. These assumptions imply that the optimal health stock decreases with age.

This situation is shown in Figure (5) by the fact that the optimal health at the younger age, H_0, is greater than H_1, the optimal stock at the older age. higher depreciation rates increase the cost of holding health capital stock. We adjust to this by holding a greater amount of health in periods when health is less costly. In old age, health depreciation rates are extremely high, δ_D, and optimal health stock falls to H_{min} at point B.

This conclusion is consistent with the observation that elderly people purchase a greater amount of medical care, even as their health deteriorates. Grossman explains the phenomenon.

Gross investment's life cycle profile would not, in general, simply mirror that of health capital. This follows because a rise in the rate of depreciation not only reduces the amount of health capital demanded by consumers but also reduces the amount of capital supplied to them by a given amount of gross investment.

Other features of the model suggest that people generally will increase their gross investment (the amount of dollars spent) in health as they age. This suggests in turn that the elderly would demand more medical care than the young, as we frequently note to be the case.

Thus, the pure investment model generates the prediction that optimal health will decline as the person ages. Will this prediction change when we more realistically assume that an individual also will value health for consumption reasons (good health makes one feel better) ? The issue turns on whether older persons get more or less direct utility from the enjoyment of healthy days. If people increase their valuation of healthy days as they age, this off-

sets the predicted health stock decline somewhat. However, we have no theoretical reasons, intuition, or empirical evidence to suppose that this is true.

Wage Rate:

Figure (5) illustrates the effect of a change in the wage rate on Ed's optimal level of investment. Increased wage rates increase the returns obtained from healthy days (8 hour's work will bring in $ 128 rather than $ 120 if the wage rate rises to $ 16 from $ 15). Thus, higher wages imply a higher MEI curve, or MEI′.

Assume now that the original MEI curve describes the lower-wage case and yields optimal health stock, H_0. MEI′, above MEI, shows the marginal efficiency of investment for someone with higher wages. At new equilibrium point C, the higher age will imply a higher optimal level of health stock, H_2, in this pure investment model. The rewards of being healthy are greater for higher-wage workers, so increased wages will tend to increase their optimal capital stock.

The model illustrates an additional rich implication of the wage factor. Consider that when Ed retires, his wage effectively drops to zero. The pure investment version implies that he would change his optimal health stock to

H_{min} upon retirement. Once he retires, he would make no further investment in health, but instead would allow health to depreciate until death.

How would our analysis be amended by considering the consumption aspects of health that is, that good health makes one feel good? First, the retired person would presumably continue to obtain utility directly from healthy days. Thus, optimal health stock would not necessarily drop to H_{min} directly upon the person's retirement, but it would do so only when depreciation rates became sufficiently severe.

Second, if retirees and those who are still working obtain utility directly from healthy days, then the only significant change upon retirement would be the pure investment aspects. Therefore, even when we include the consumption aspects of health, we would expect people to reduce their health stock upon retirement.

Education:

Education is of special interest in the demand for health. Recall that education is seen as a factor that improve the efficiency with which one can produce investments to health and the home good. The effect of education is illustrated in Figure (5). Here the MEI curve illustrates

the marginal efficiency of investment for the consumer with a low level of education (measured, for example, by years of schooling), while the MEI′ curve illustrates the same person with a higher level of education. This model indicates that because education raises the marginal product of direct inputs, it reduces the quantity of these inputs required to produce a given amount of gross investment.

It follows that a given investment in health can be generated at less cost for an educated person, and thus he or she experiences a higher rate of return to a given stock of health. The result, as shown, is that the more educated person will choose a higher optimal health stock, H_2, than less educated person who will choose H_0.

This explains the widely observed correlation between health status and education. Educated people, ***ceteris paribus***, tend to be significantly healthier. However, this explains only the correlation of health status and education from the supply side in that it considers only the increased efficiency with we produce health. One also might wish to explain education from the demand side.

Education people are likely recognize the benefits of improved health. They may enjoy eating nutritious food or

doing physical exercise. They may recognize the dangers of smoking and the long-term problems of overexposure to the sun. They may enjoy feeling and looking good. As such, all else equal, they would have a greater taste for health relative to other goods.

The demand for health due to education is difficult to separate from the supply effect of education, which implies more productivity in producing health. Clearly, however, both exist and are important.

Uncertainty:

The Grossman model starts with the assumption of perfect certainty as to future outcomes as do most economic models. However, outcomes are not always certain. What impact does uncertainty have on the optimal level of health investment and health capital ? In a given year, Ed Kramer has to choose how much to invest in health care. Alternatively, he may choose to consume his resources, or he may choose to invest in a nonhealth financial asset, which by assumption is less risky than health investment. Following Chung (1996), two effects can occur.

Suppose that Ed's earnings depend on his health. If he were to fall ill next year, his ability to work and his

earnings (the return on his next year's health capital) would fall, and Ed is concerned about that risk. An additional dollar of investment in health capital this year will help insure against that loss by increasing his health capital stock, and hence his earning and consumption next year. This first effect, the improvement of future earnings, will thus lead Ed to increase his investment in health capital to reduce his risk.

However, Figure (5) shows that the marginal efficiency of investment is downward sloping. This second effect means that unless changes occur in productivity, increased health investment has a lower return. Therefore, if the increased investment this year has no impact on Ed's ability to earn income next year (Ed gets headaches, but he still can work full days for a full day's pay), then increased risk will affect health investment negatively by lowering the return on the health investment.

We do not live in an either / or world, so if the first effect is larger than the second, increased risk will lead to more investment in health capital. If the second is larger than the first, Ed either will choose current consumption rather than health investment or alternatively will invest in a financial asset that, by assumption, is less risky than health investment.

Pupulation and Human well being

Data items \ Region	year	Africa	Europe	North America	Central America	South America	Asia	Unit
Life expectancy	1995	53.8	72.6	76.9	71.7	69	66.2	years
Total fertility rate	1995	5.3	1.5	1.9	3	2.5	2.7	children/woman
Infant martality	1995	86	12	7	33	36	56	per thousand live birth
Crude death rate	1995	12.9	11.5	8.6	5.3	6.8	7.9	per 1000 people
Percentage of population:								
Rural	1955	65	26	24	34	23	65	%
Urban	1955	35	74	76	66	77	35	%
Underage 15	2000	43	15	21	35	30	30	%
Overage 65	2000	3	15	12	5	6	6	%
Motor vehiclee	1991	0.02	0.27	0.72	0.11	0.09	0.03	per capita
Television	1994	40	412	793	171	171	130	per 1000 people
Cities with population Greater than 75000	1995	44	84	51	21	38	184	

From : World Resources 1998-1999, Oxford Univeresty press.

Answers of Questions
On Part I

Question # 2: Multiple Choice:

1- (c)	2- (b)	3- (c)	4- (c)	5- (a)
6- (b)	7- (e)	8- (c)	9- (c)	10- (d)
11- (a)	12- (a)	13- (a)	14- (a)	15- (d)
16- (a)	17- (a)	18- (a)	19- (a)	20- (c)
21- (a)	22- (e)	23- (a)	24- (a)	25- (a)
26- (d)	27- (a)	28- (d)	29- (d)	30- (d)
31- (d)	32- (a)	33- (d)	34- (d)	35- (d)
36- (a)	37- (c)	38- (e)	39- (a)	40- (b)
41- (a)	42- (a)	43- (a)	44- (a)	45- (c)
46- (c)	47- (a)	48- (d)	49- (a)	

Question # 3: Define the following:

1- **Optimal environmental quality**: Refers to the optimal level of production where the marginal private benefits equals the marginal external cost.

2- **Assimilative capacity**: Refers to the capacity of environment which is able to absorb and render harmless waste products. It is assumed that assimilative capacity is constant.

3- **Ecologically stable output**: Refers to the level of output where there is no external cost and this level represents also a zero level of production.

4- **The marginal external cost**: Is increasing as the level of output increases (directly related).

5- **The marginal private benefits**: Is decreasing as the level of output increases (inversely related).

Question # 4: True or False:

1- True	2- True	3- False	4- False
5- True	6- True	7- True	8- True
9- True	10- True	11- False	12- False
13- True	14- False	15- False	16- False
17- False	18- True	19- False	20- True
21- False	22- True	23- True	24- True
25- True	26- False	27- False	28- True
29- True	30- False	31- False	32- True
33- True	34- True	35- True	36- True
37- False	38- True	39- False	40- True
41- True	42- True	43- True	44- False
45- True	46- True	47- False	48- True
49- True	50- True	51- True	52- True
53- False	54- False		

Question # 5:

1- Benefits for producer of pollution.

2- Costs for affected person.

3- d , c+d , Y_2 , producer , affected person.

4- c , d , d , d , c , d , Y_2 , Y_1

5- a , b

Question # 6:

Check the book.

Question # 7:

1-(2) , 2-(10) , 3-(14)

Question # 8:

Check the book.

Question # 9:

Check the book.

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